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Sailing with Amateur Radio

Selected excerpts from the pages of *Ham Radio HORIZONS*

GOING SAILING WITH AMATEUR RADIO

Selected excerpts from the pages of
Ham Radio HORIZONS

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Introduction

Sailing and Amateur Radio — two great hobbies that go together in a most complimentary way. The August, 1977 issue of *Ham Radio Horizons* pointed out some of the reasons for this great combination, and told of some experiences that people have had with Amateur Radio aboard. The response from our readers was great, and many wanted to know more.

This booklet is intended to tell you more, to acquaint you with the steps necessary to become a radio amateur, and to give you some insight into what amateur radio can do for you as a sailor or yachtsman. Two areas stand out in the articles — emergency communications and companionship. These features have been useful to blue-water sailors and lake and river craft alike. And with Amateur Radio operators available in approximately 300 countries, the usefulness of this service is not limited to American waters alone!

Before I go into more detail, however, let me point out that I am talking about the pleasure-craft type of sailing. The cruise liners and merchantmen and tankers have their own uses for radio, and a strict set of rules and procedures to go by. (You'll often find, however, that the radio officer on these ships is also a radio amateur, and sometimes uses the amateur frequencies for personal enjoyment when he is not on duty or involved in ship's business.)

When I mention safety, don't think that I advocate amateur radio as your only means of communication — far from it. In normal times, amateur radio can provide hours of companionship with other people, many of whom have an interest in sailing, in all parts of the world. In troubled times, amateur radio can provide a pipeline to thousands of people who are eager to help, and have proven time and again that they know how to handle emergency situations. Diversification of interest and versatility of talent is what makes the amateur radio world unique. There are no stereotyped, hard-line, set of "shall and shall-not" procedures to hamper your enjoyment. Amateurs abide by a few common-sense rules that are designed to make life easier for everyone, and to provide a common basis for exchange of the most essential information. The atmosphere is relaxed, informal, friendly.

Then, too, your exposure to the workings of radio through the acquiring of skills necessary to obtain an amateur radio license will come in good stead when you use your commercial or marine-band equipment. The differences between amateur equipment and commercial- or marine-band radios are sometimes subtle, sometimes marked, but there are good reasons for the differences being there.

For one thing, commercial equipment must meet certain technical standards and remain close to a prescribed frequency in order to assure that it can be used to communicate with another boat or with a shore station. For that reason, adjustments to the equipment must be made by a qualified, licensed, person who has the necessary test facilities to maintain these standards of operation. No vital adjustments are available to the operator. In most instances this is good, and the equipment serves the purpose. Sometimes, though, the equipment cannot do the job because of outside circumstances. As an example — the power output circuitry of a transmitter is adjusted to work with a fixed antenna of exact dimensions, and as long as the antenna and its surroundings remain intact, the system works fine. However, if anything should happen to the antenna system, the transmitter is no longer capable of providing the necessary power to it, and there are no adjustments that you can get at to make it work. In amateur equipment, the circuitry is capable of providing power to a wide variety of antenna systems, and many of the adjustments and controls are accessible to the operator, allowing you to use a jury-rigged antenna to provide communications in case of need. Not only is the possibility there, but through practice in using this type of "system flexibility," you'll gain knowledge about when your commercial equipment should work, and when it most

likely will not work. This knowledge will extend to the frequency and propagation part of the radio world too. A marine frequency at 6 or 8 MHz is going to behave very much in the same manner as an amateur frequency nearby at 7 MHz; you can experiment and learn on the amateur bands, but the marine channel is strictly for business.

Is it hard to learn to be a radio amateur? No, not for anyone who has mastered the skills necessary for safe pleasure boating. You come by them gradually, just as you did with your sailing. No one is born with the knowledge of how to read the surface of the water, the wind markings or submerged-obstruction patterns upon it, or the meaning of the buoys along the way. I'll bet that your charts were a complete mystery at first glance, but you gradually became familiar with them, and with the rules of the road, so that you could do things safely and still enjoy a great and relaxing pastime. It's the same with amateur radio. You start small, learn the basic rules, the language, and the things to avoid. As you use the acquired knowledge, it gets easier, and your field expands. You learn to read the characteristics of the various bands of frequencies, knowing what to expect from them, just as the experienced hand knows when the sky is telling him to run for the harbor, or when the swell pattern tells him that there is a change in the bottom or currents.

But, lest I spoil the impact of some of the following stories, I'd best leave that subject for a while. You'll find much to help you make the decision in these stories, and, once the decision is made to join us in amateur radio, there's plenty of material in these pages to help you get there. There are examples from articles about learning the radiotelegraph code (an international requirement), and a couple of articles about how amateur radio is used, and has been used, aboard power cruisers and sailing craft; how it has saved life and property, how it provides companionship to ports around the world.

There is some information about single-sideband (ssb) voice equipment, what it is and how it got that way. More and more services are using this efficient type of transmission, and you'll see why it is more efficient, both in terms of power consumed and radio spectrum occupied.

Propagation of radio waves is always an interesting and useful subject, because knowledge of how signals get from one place to another will help when you want to talk to a particular part of the world. It'll also explain why your radio seems to work at times, but at others you cannot raise anyone.

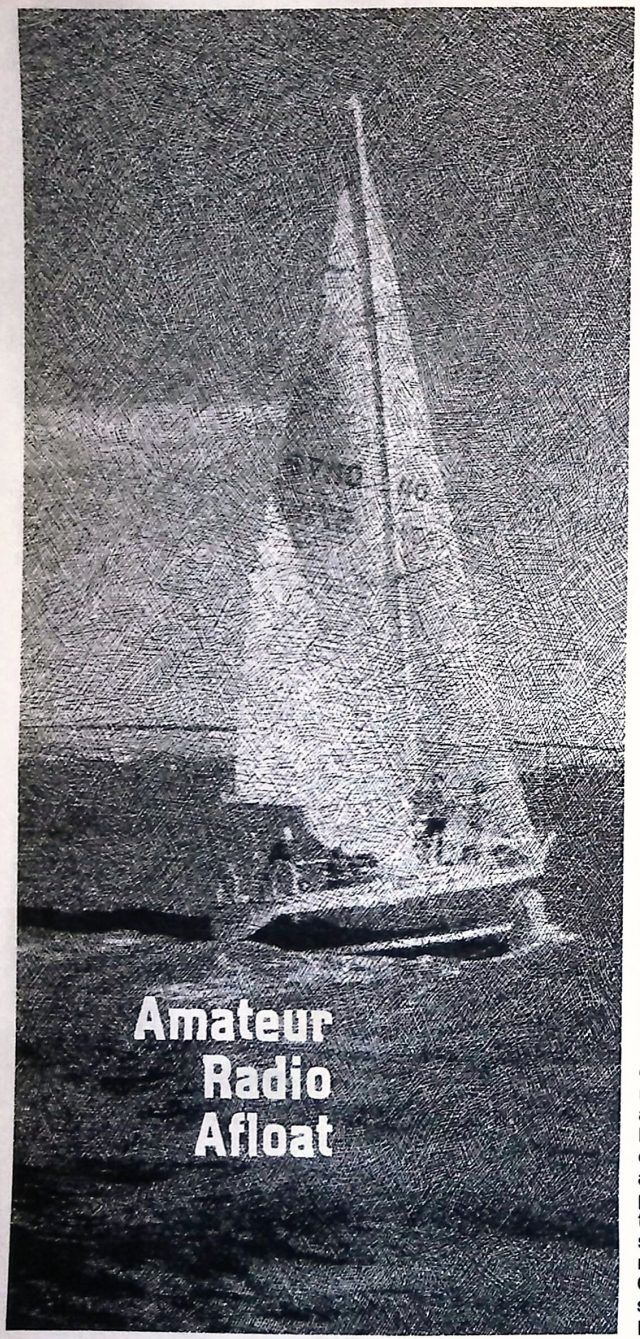
Almost hand-in-hand with propagation is sunspots — solar activity. In fact, the sun has a direct bearing on how well or poorly radio waves propagate through our ionosphere. The article about this cause and effect will help you understand both the short- and long-term implications of rising and falling solar activity.

We have a story about time signals and the stations that send them around the world. I'm sure you need to know the correct time for many reasons, especially on longer voyages, so this article tells you about a couple of the main United States and Canadian stations, and lists many others that you can find in all parts of the globe. Some of them broadcast severe-weather warnings and predictions of solar upsets too.

Many of you have CB radios, at home, in your car, on your boat, and we've included an item about how CBers can become hams. The steps are not that difficult, and the advantages are many. The two services are complimentary, and coexist beautifully, as long as you recognize the limitations of each of them.

So, plan to take Amateur Radio with you on your next cruise. The versatility, companionship, and safety that it will add to your life will be far more valuable than the modest cost and the small space that it occupies.

Thomas McMullen, W1SL



Amateur Radio Afloat

BY HERB JOHNSON, W6QKI

The America's Cup races — you've heard of them, even watched parts of the big event on television. It's a beautiful and exciting scene, with acres of sail catching the wind, enough whitecaps and spray to make the crew step lively, and hordes of spectator craft being herded about by the Coast Guard and race officials. The onlookers seem to be having a great time, and those ashore are caught up in the enthusiasm of the day. Aboard the racing yachts the atmosphere is all business — they're enjoying the race too, from the viewpoint that all competitors enjoy a keen and well-fought race. This is the *World Series* of boat racing; the culmination of years of training and preparation. Trials and eliminations have narrowed the field to the best sailing boat and crew that each participating nation can offer. They're here to try to capture the prize Cup — one that was first won by the yacht *America* in a series of races that started in 1851.

Behind the scenes, Amateur Radio is doing it's part in the race, too. I am thinking particularly of the America's Cup race in 1974. Amateur Radio was useful not only at the time of the race, but also during the long trials to select the defender to represent the United States through the New York Yacht Club. There are a lot of people interested in keeping in touch with how things are going: people who provided backing for the boats, of course, and friends and relatives of the crew members and the news media. When you have a crew of, say 7 to 12 men on each boat, the involved audience can grow to sizable proportions. I had an Amateur transceiver — it weighed only seven pounds and was not much larger than an average CB set — set up on board a spectator boat that was keeping track of the progress

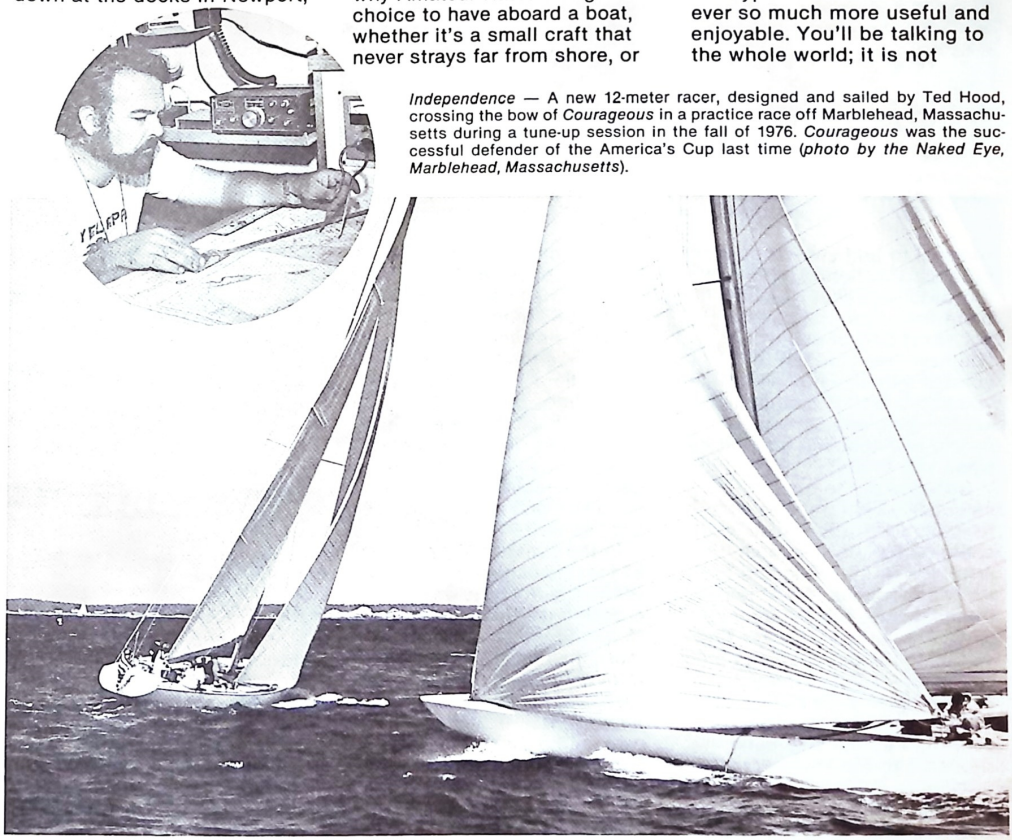
of the race between the *Intrepid* and the *Courageous* during the elimination trials. This *Intrepid* was backed by a West Coast syndicate, called Intrepid West, so there was a lot of distance to be covered to let the people know what was happening.

A regular schedule was set up with some Amateur stations on the West Coast, and that operation grew to a large network involving stations in San Francisco, Los Angeles, Newport Beach, San Diego, and Seattle. Eventually, some stations in Miami, Houston, and the Great Lakes area joined in. There is an amusing sidelight to this, too. The man in charge of public relations for Intrepid West had a little office down at the docks in Newport, Rhode Island, and as soon as the boats were out on the sound, he was out of touch with what was happening. One day, during a telephone call to the West Coast, someone there told him how things were going at the trials. He was astounded, and wondered how they knew so much more about it than he did. Later, he talked to me about it, and I gave him a spare receiver and set it up so he could listen in to our Amateur network. That was an exciting time, and an instance when Amateur Radio was providing one of its great services — keeping friends and relatives informed.

Why amateur radio?

There are scores of reasons why Amateur Radio is a good choice to have aboard a boat, whether it's a small craft that never strays far from shore, or a *blue-water* boat that is used for ocean sailing. But before I get into some of the reasons, let me clearly emphasize that having Amateur radio aboard in no way relieves you of the responsibility of having on board the communication facilities that are required by the Coast Guard; they require that you be able to communicate on channels that they use for safety and advisory messages, and those channels that they monitor for distress calls.

Amateur Radio can handle emergency messages, too, and I'll tell you more about that shortly. But the vast coverage of ham radio, in terms of distance, and in the numbers of people who are hams, makes this type of communications ever so much more useful and enjoyable. You'll be talking to the whole world; it is not



Independence — A new 12-meter racer, designed and sailed by Ted Hood, crossing the bow of *Courageous* in a practice race off Marblehead, Massachusetts during a tune-up session in the fall of 1976. *Courageous* was the successful defender of the America's Cup last time (*photo by the Naked Eye, Marblehead, Massachusetts*).

A neat shipboard Amateur radio installation using an older tube-type transceiver with a crystal-controlled fixed-frequency attachment. These rigs do their job well, but place a burden on the vessel's power source just to keep the tubes warm.

unusual to find several boating enthusiasts sharing the airwaves with you. How much more friendly and interesting your next port of call will be if you have been talking to someone there who can advise you about facilities, supplies, anchorages, and perhaps be part of a welcoming committee when you arrive.

Because of the great selection of frequencies that Amateurs are able to use, you could be talking to almost anyplace — from England to the Mediterranean to Africa; from Japan to the Philippines to Australia. You'll always find someone to chat with, and on almost any subject from chess to anthropology to sailing to scuba diving. None of this is permitted on the channels allocated to the Marine radio service.

Amateur Radio has more than paid its way in providing emergency communications, too. This phase of Amateur Radio is well covered in an article by Anthony Curtis, K3RXK, elsewhere in this issue, but let me tell you of a recent case where a combination of the right equipment and the technical skill acquired while studying for the Amateur license was instrumental in getting people out of a bad situation, and perhaps in saving lives as well.

In the summer of 1976 a 61-foot (18.6m) racing/cruising yacht, the *Sorcery*, was crossing the Pacific from Japan to San Francisco. They were more than one thousand miles from shore, in a storm, when a freak wave hit the ship and rolled it over. In addition to dismasting the boat, the wave had carried away the life rafts, and disabled the engines and the source of power for their regular communications equipment.

Many of the eleven people on board were injured — one seriously. A fuel drum fell on the leg of one girl, causing either multiple or compound fractures; a very serious condition anywhere, let alone on a disabled craft in the middle of the ocean.

One of the people aboard, a woman, was a radio amateur, and had a transceiver with her. Again, it was a little 7-pound (3.2kg) box, and it was the only piece of communications equipment that was working that morning. Thanks to the study required for the Amateur license, she knew what to do, and soon they had strung a 20-foot (6m) wire across the deck — there was no mast to hoist it up on — and put forth a "Mayday" call. The first answer was from a ham in Alaska; he got in touch with the woman's husband in Escondido, California. They were joined by hams in Hawaii and in Seattle, Washington. The Coast Guard soon came up on the frequency, and not long after that the captain of a Danish freighter overheard the conversation and determined from his location that he was the nearest one to the stricken *Sorcery*. About 24 hours later he came alongside her. Meanwhile, the Coast Guard had a plane on the way to drop life rafts and pumps if the freighter was unable to do anything. A Coast Guard cutter arrived later and took the *Sorcery* in tow, and brought the injured crew aboard. Without that little Amateur transceiver, it could have been a far more tragic story.

Amateur radio equipment

You need two things to take advantage of the usefulness of Amateur Radio: a transceiver (or transmitter and receiver) for the ham bands, and a license to use it. I'll tell you more about the license and how to get it a bit later, but for the moment let's talk about equipment.

First, don't expect the dealer who handles your Marine radio equipment to know much about Amateur equipment, or to have it available. It is usually outside his line of experience, in what it will do, how it is installed, and more important, what makes Amateur Radio a natural for the sailing enthusiast.

There are several ways to go about finding a dealer who has Amateur Radio equipment, and many of these same routes can be used to find people who will help you in getting the Amateur license that you will need. In the larger metropolitan areas, a search through the *Yellow Pages* will usually tip you off to the names of a distributor of electronic parts, equipment, and supplies. These are excellent places to start. Even if these distributors don't have Amateur equipment, they will usually be able to refer you to someone who does. If that search turns up a dead-end, then you can start looking for anything or anyone connected with electronics. This can be almost anything — the local a-m radio station, fm broadcast, TV station, or a shop that repairs and sells CB, TV, and Hi-Fi sets. It is not likely that many of them will be involved directly in Amateur Radio from the equipment standpoint, but they will usually have heard of one or several Amateurs, and can help you get in touch with them.

The Amateur, in turn, will almost always be happy to help in any way he can to make it possible for you to join his fraternity, and can steer you to a dealer who sells equipment. He can also help by letting you look through some of the Amateur magazines and journals, where all of the better manufacturers advertise their wares and list their dealers and distributors. If you live in a town so small that it has no local electronic facility of any kind — and it would have to be a small place indeed that had no nearby a-m or fm broadcast station — try the maintenance people at the local telephone company. Amateur Radio is not unknown to those who deal in communications-by-wire.

An amateur radio installation on the bridge of a power cruiser. The small white box to the right of the transceiver is an antenna tuner which permits the use of a random length of wire for all bands. The equipment is secured by brackets.

Oh, yes, I would like to point out that CB, while it certainly has its uses, falls far short of the capability of Amateur Radio. It has limited power (5 watts) and very short range. Further, the Coast Guard does not monitor CB, and usually does not have equipment capable of operating on CB frequencies.

Amateur Radio, on the other hand, allows the use of up to 1000 watts of power in the final stage, and can be operated over such a wide range of frequencies that it is not hard to find a frequency band that will cover the required distance. Further, most military (Coast Guard) equipment has tremendous frequency-changing capability, which will allow them to find you on a ham band, and, in case of emergency, communicate with you there.

What kind?

In terms of distance to be covered by Amateur Radio communications, there are two categories to consider. The globe-spanning type of operation that I have been talking about is done in what is termed the high-frequency part of the spectrum. This ranges from the segment just above the broadcast band (1.8 to 2.0 MHz) up to the 10-meter band (just above the CB channels). The most useful areas will be the 40, 20, and 15 meter bands (7.0, 14.0, and 21.0 MHz). Equipment that will cover these three bands will allow you to communicate with Amateurs at home stations or on other boats at distances varying from dozens to thousands of miles, depending upon the reflectivity

The author operating aboard his sloop *Vector*. This compact installation includes equipment for Amateur-band SSB, 2-meter fm, and vhf Marine Band operation. There is also room for an antenna tuner and a crystal-control adapter for the SSB transmitter.

or absorption of the ionosphere at the time. Maritime operation is not permitted in most areas on the two lower Amateur bands (160 and 80 meters).

An area of increasing importance, especially to those who do not venture far from shore, is vhf, (Very High-Frequency). The Amateur two-meter (144-MHz) band is the most popular, and is made more useful by the growth of repeaters on that band. A repeater is a station that receives a signal, amplifies it, and retransmits it with much greater power. They are usually located where they can take advantage of height — a mountain, hill, or tall tower — to increase their range. It is not unusual to be able to talk across distances up to 50 or 75 miles (80-120km) while using a low-powered unit connected to a 19-inch (48cm) antenna at the top of a mast.

There are several types and brands of equipment to choose from, as you will discover when you start talking to dealers or Amateurs about what to buy. You can make a reasonable choice by looking at the specifications and keeping a few simple requirements in mind. Two uppermost thoughts should be power consumption and frequency range. For best economy in power consumption, the unit should be all solid-state, that is, transistorized. Tubes require that the filament (heater) be kept warm all the time, thus placing a heavy drain on your power source even when you are just listening. A few of the modern transceivers have tubes in the high-powered output stage only, with the rest of the circuitry handled by transistors. Some of these have provisions to bypass the tube section, allowing an output of just a few watts instead of the hundreds available with the tubes. Among Amateur transceivers that provide output in the better-than-hundred-watt range are the Atlas 210X, 215X and 350-XL; Ten-Tec Triton IV; the Yaesu FT-101E, and the Heath SB104 and HW104. All of these can be operated directly from a 12-volt supply or battery, and cover the high-frequency Amateur bands.

Installation

There are three things to consider when installing Amateur equipment on a boat; transceiver placement, antenna location, and a ground system. When you install the transceiver, convenience in operating it and protection from salt spray or leaks should be kept in mind. This usually means that the equipment will be in a compartment or cabin, where it can be used by an operator in more or less comfortable surroundings. If you must hear what is being received from an exposed or remote location, an extension speaker is the answer. Most modern transceivers are set up so you can plug in an external speaker for just this purpose. Bear in mind that when you are protecting the transceiver from spray and leakage that the heatsink fins on the back of the unit require good free-air circulation for proper cooling.

If a plug-in or quick-disconnect type of mount is available for the equipment you choose, it might be a

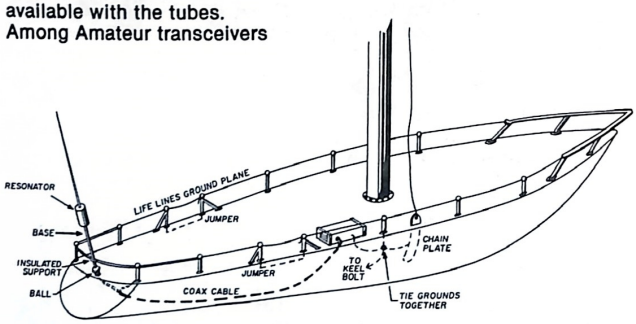


Fig. 1. The life lines on a sailboat can be used as a ground-plane system. Jumpers must be used to bridge the gap at the gates. Life lines, chain plates, and metal keel should all be tied together to obtain a good ground for the antenna to work against. A ball mount and insulated support fastens the antenna securely.

worthwhile investment. The easy-removal feature will allow you to store the equipment in safer or dryer surroundings during extended periods of inactivity (or you can take it home and use it between voyages).

The equipment is usually supplied with enough heavy cable to reach to the battery in an average automobile, but this may not be enough for some boats. The cable can be extended by using a heavy wire, 10 or 8 gauge (2.5-3.5mm) to splice on as needed. A fuse or circuit breaker should be installed at the battery end of the run.

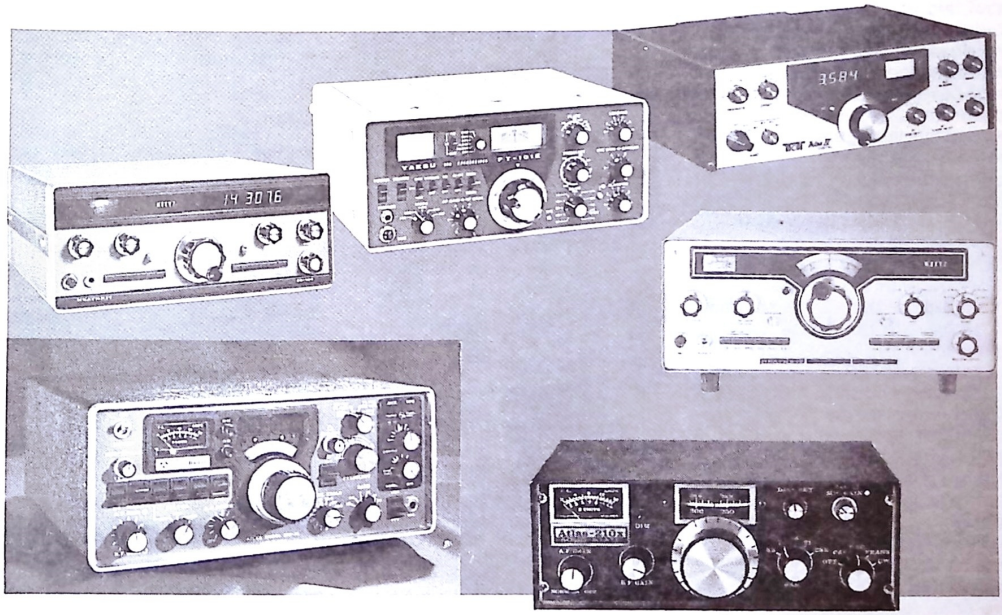
Grounds

Ground connections can be as varied as there are types of boats. Sailing craft will require treatment different from power boats. Large bodies of water provide an essentially perfect *ground plane* for the launching of a radio signal into the ionosphere, but the problem appears when you try to connect to it.

Of course, a good ground connection at the transceiver itself is the first place to start, and this should not only be a ground for the power source but a ground for the radio-frequency energy as well. If your craft has a steel or aluminum hull, you are in luck; a good connection to the hull at the end of the coaxial cable from the transceiver, and at the transceiver, will do the job nicely.

Another type of ground can be made by using metal life lines, if the boat has that type running along the starboard and port sides (see **Fig. 1**). These lines can form a *counterpoise* system that is just as effective as a direct connection to the ocean or lake. You must watch for breaks in the life line, such as at the gate used to board the vessel, or at the bow or stern. Where such gaps occur, a jumper wire or cable must be used to bridge the open space to complete the ground. This can be done by running a stainless steel strap under the deck between the stanchions to connect the starboard and the port lines together. The jumper doesn't have to be very thick, but should be 3/8 to 1/2 inch, (10-13mm) wide. Braided copper or bronze strap will work, also, but stainless is preferable because of its anticorrosion properties. Be sure that any fittings in the life lines are clean, tight, and make good metallic contact.

A keel makes an excellent ground system, especially if it is of the solid-lead type. All that is necessary is to run a good ground strap from the equipment to the nearest keep bolt. Be sure, however, that you make a good clean electrical connection to this bolt. You can also drill and tap into the lead for a connection separate from a keel bolt if you like. One type of keel to avoid is the type that is made up of several pieces of metal; they may not all be making good contact with each other, and would serve as a poor ground. A solid-metal keel is a good ground even if it is encased in a wood



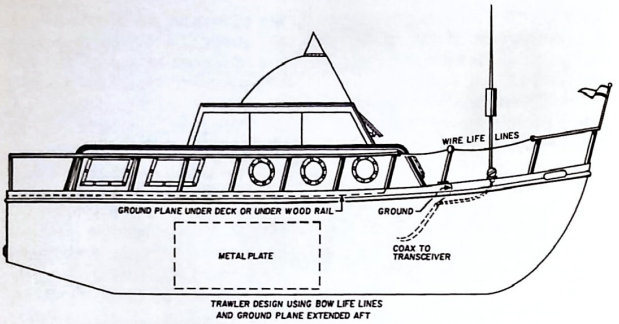

WIRE LIFE LINES
GROUND PLANE UNDER DECK OR UNDER WOOD RAIL
GROUND
METAL PLATE
COAX TO TRANSCEIVER
TRAWLER DESIGN USING BOW LIFE LINES AND GROUND PLANE EXTENDED AFT

Fig. 2. Some power boats have wood rails, so you must place a ground plane under the deck, or under the rail itself. This can be a piece of stainless steel strap or copper braid. A metal plate, either inside or outside the hull, can be used by itself or in addition to the life lines or rail.

or fiberglass hull. The insulating material (wood or fiberglass) still allows efficient coupling between the metal keel and the water around it.

A boat which has neither life lines nor a metal keel, such as a power boat with a wooden or fiberglass hull, will likely require a metal plate for a ground (**Fig. 2**). It can be either inside or outside the hull. An internal plate should be at least 20 square feet (1.8m^2) in size, and laid up against the hull below the waterline. It can be made up of two or more sections, connected together and covered with fiberglass for protection. The metal can be quite thin, and stainless steel is best.

An external ground plate will be more difficult to install, but it can be smaller in area. An adequate size would be approximately 10 square feet (0.9m^2). It can be cemented in place below the waterline, and covered with fiberglass. Do not depend on the propeller shaft to provide an adequate ground for radio equipment and antenna systems.

You can tie several ground systems together for even greater efficiency. For example, you can connect the life line stanchions to the keel with stainless steel strapping. The mast should already be connected to the keel and/or life lines for lightning protection, but check to be sure. Don't forget to run a good strap to the engine and the battery ground (usually negative) terminal. You can't install too many ground systems, but you may easily have too few.

Antenna systems

I have found that the most useful antenna for Amateur Radio aboard boats is a vertical whip with the resonating coil located near the center. These are made for use in Amateur mobile installations and work well when installed on most boats; they consist of a base or bottom section, a coil or resonator that is designed to make the antenna work in a particular band of frequencies, and a top section that can be adjusted to fine tune the system to a particular frequency.

A number of manufacturers make these antennas, and they are sold by distributors and dealers in Amateur equipment. There is not a great difference in performance between the various brands. Those with the larger coils are somewhat more efficient, but because the ocean serves as a perfect platform to launch the signal, most brands work well. A very popular one, the *Hustler*, made by New-Tronics, works very well in most marine installations. You have to purchase one base, or mast section, one universal ball mount, and a resonator for each frequency range required. Each resonator comes with the

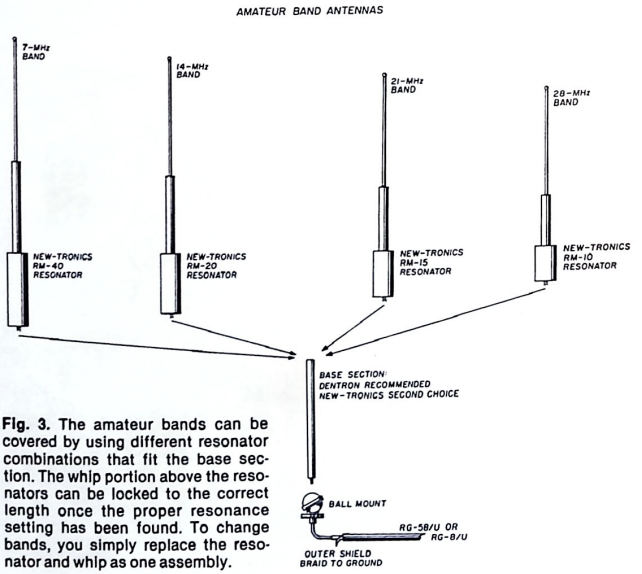


Fig. 3. The amateur bands can be covered by using different resonator combinations that fit the base section. The whip portion above the resonators can be locked to the correct length once the proper resonance setting has been found. To change bands, you simply replace the resonator and whip as one assembly.

necessary top, or whip, section. Once the whip has been adjusted and locked to the correct length, it can be left alone for that frequency. When you change bands, it is only necessary to change the resonator. Some antenna configurations for use on the Amateur bands are given in **Fig. 3**; **Fig. 4** shows how the Amateur antennas can be modified for use in the various Marine bands.

It is worth mentioning here that Amateur transceivers are not type-accepted for the Marine radio service and should not be used there. However, you can listen there as much as you like, and a modified Amateur antenna will perform very well when attached to your regular Marine transceiver. At any rate, it is worth knowing what must be done to make the maximum use of the antennas available on your boat.

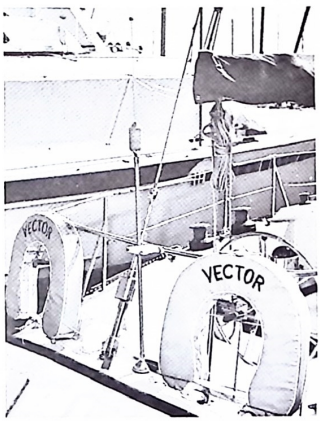
One problem with the New-Tronics antenna is that it is built with a hinged base section (to permit the top portion to be placed in a horizontal position to allow a car to be driven into a garage). In marine use this joint tends to loosen up. A possible solution is to buy a Dentron, or Swan, base section instead.

There are two models of the *Hustler* available: one is rated for transmitter power up to 400 watts; the other will handle 1000 watts. Either one is satisfactory for marine use.

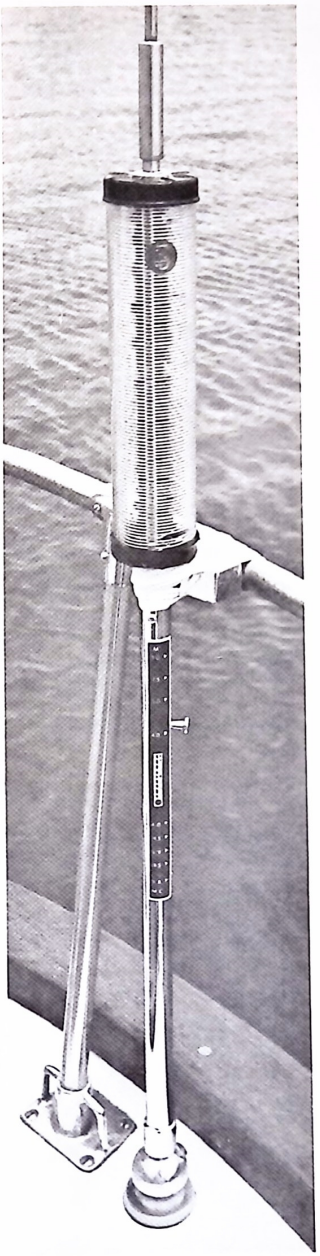
The vertical whip antenna has the advantage that you will still have an antenna even if the mast and all the rigging has been carried away. Changing bands does require a trip to the stern, but this doesn't have to be done too often, and is a small chore. A drawback of the whip is that it requires an exact adjustment for resonance at the operating frequency. A slight misadjustment will cause a severe loss of efficiency.

On most sail boats the best location is at the stern on the afterdeck. A ball mount such as is used on an automobile for cowl or deck mounting works well to get the antenna coax cable connections under the deck.

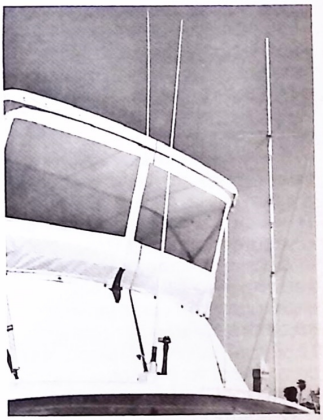
Further support for the antenna may be secured from the stern pulpit if there is one (**Fig. 5**). The ball mount at the very bottom of the whip antenna does not provide quite enough support, since in heavy seas the ship may be violently



A type of multiband whip antenna that requires that the coil and top section be changed to use a different band. A plastic block holds the whip for stability.



This multiband antenna permits operation on different frequencies by adjusting the loading coil. A block and tape secures the whip to the rail.



Considerable operating flexibility is provided by the vhf antenna (foreground), and the multiband vertical whip to its right.

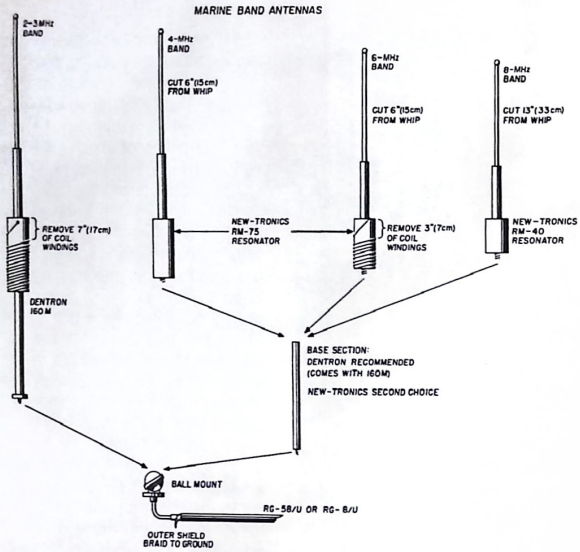


Fig. 4. To use the same antenna mounting system for the Marine radio frequencies, you can modify the resonators. Turns of wire can be removed from the coils, and a waterproof covering or spray applied after the modification. Color coding the resonators will help select the proper one for a particular band when you are in a hurry.

thrown back and forth. Also, people may grab the antenna for a hand hold. An insulated clamp arrangement where the whip goes near the stern pulpit will take care of this problem. Since there is only low rf voltage on the lower base section, insulation is not critical. A block of plastic with glass tape or metal clamp arrangement is adequate. You can probably find a suitable insulated support of the type designed for supporting the fiberglass-whip marine antennas.

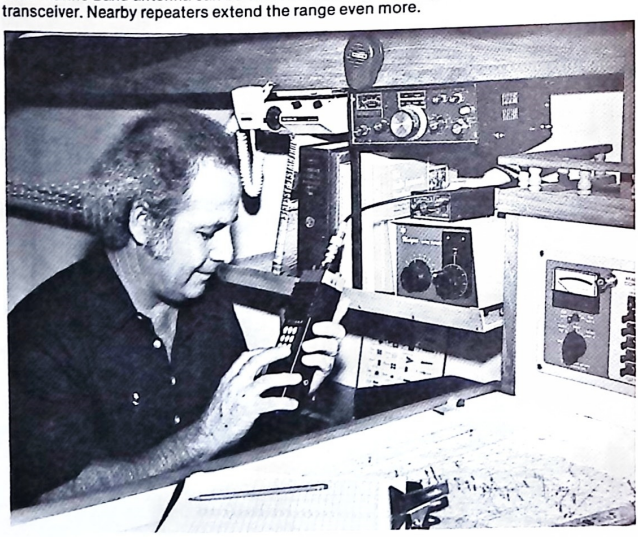
If the sailboat is a ketch or yawl rig, the mizzen boom may present a problem (**Fig. 5B**). The whip can be tilted back at 45 degrees or more if necessary without deteriorating performance to any great extent, and this will usually solve the clearance problem. This position may make it less convenient to change resonators, but is about the only solution.

The poorest location for the whip antenna is on top of a mast. Contrary to what you may think, it will not work any better on top of the mast since the radio signal is essentially launched from the surface of the ocean, so by all means, keep the whip down where you can easily reach it. Antennas for vhf present a different situation; because propagation is line-of-sight, with no benefit from an ionospheric reflector, vhf antenna height is very important.

It is sometimes difficult to find a good place to mount the antenna on a power boat. An important consideration is what type of ground system will be used. If the hull and superstructure is metal, the whip may be mounted almost anywhere since a ground connection will be available all over. If the hull is metal, but the superstructure is not, it's best to mount the whip down low, near deck level to have it close to the hull for the ground connection. If the hull is not metallic, a ground system must be established and this will determine the best antenna location.

Most offshore cruisers have a rail of some sort running along the deck on both sides. Often the portion up forward near the bow is metallic cable, the same as is used on sailboats. Most of the rail running aft is wood, but if the

A vhf Marine Band antenna can be used to increase the range of an amateur hand-held transceiver. Nearby repeaters extend the range even more.



underside can be lined with a narrow strip of stainless steel, ¼ inch (6.5mm) wide, or greater this will make an excellent ground plane. Remember that the ground straps must be jumpered at the gates. The whip can then be mounted anywhere near the rail, on the port or starboard side, or up forward near the bow. The coax cable outer shield should be connected directly to the life line/hand-rail ground system.

If a rail-level ground plane is not practical, it may be possible to install one under the deck. A strip of stainless steel can be run down both sides under the deck, or alongside the hull.

Insulated backstay antenna

This type of antenna requires an antenna tuner for adjusting its resonance to the desired frequency. The choice between the vertical whip and an insulated backstay depends on individual circumstances and requirements. The primary advantage of the insulated backstay is that it can be resonated to any frequency by adjustment of an antenna tuner which can be located near the transceiver. Thus, you can quite easily change bands without leaving the cabin.

Insulating the backstay is a relatively expensive operation, and has a disadvantage in that loss of the mast in a storm results also in loss of the antenna.

Another favorite among sailors is a doublet, or dipole, antenna that can be hoisted on a halyard. This is similar to many antennas that are quite successful at home stations, and can provide excellent results. The ends should be fitted with small *egg* insulators so that any moisture in the halyard will not effect the performance.

License requirements

Any person who operates a radio transmitter of any kind must have a license to do so, and the license required to operate Amateur equipment is, naturally enough, an Amateur license. There are several grades of Amateur license available, ranging from the Novice who is allowed to use only Morse code within well defined frequency segments, up to the Amateur Extra, which allows all privileges on all Amateur frequencies. The Novice examination consists of sending and receiving Morse code at 5 words per minute, and a written test on Amateur rules, operating procedure, and basic electronic theory.

The Amateur General class license exam encompasses more advanced theory and requires a code speed of 13 words per minute. This class of license carries both code and voice privileges throughout the Amateur bands but still within certain segments. The Advanced and Extra tests require even more theory and the Extra requires a higher code speed.

There is also a Technician class license, which is similar to the General in written content, but with the 5-word-per-minute code requirement. The Technician licensee has phone (voice) privileges on the vhf bands, and code privileges in the Novice segments on the high-frequency bands.

To take advantage of the frequencies that will provide the most useful and interesting communications, a General class license should be the minimum that an ocean-going sailor acquires. The Amateur 20-meter (14-MHz) band is very popular for talking from one continent to the other, and the 40-meter (7-MHz) band is more useful when closer to shore — although at times it becomes an intercontinental band too.

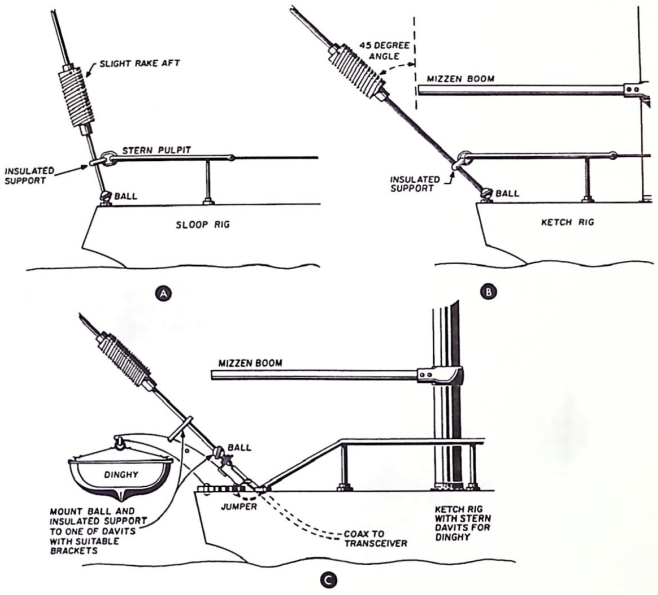


Fig. 5. The mizzen boom on some sailing craft may require some experimenting to find a way to mount the antenna so that it does not interfere. The antenna can be as much as 45 degrees from the vertical without seriously effecting performance. An insulated support bracket should be used to hold the antenna secure — the ball mount will work loose under the erratic motion of a boat. In all cases, the braid on the coaxial cable should connect to the nearest ground with a heavy wire or strap. Exposed ends should be treated or sealed to keep moisture out of the cable. The drawing is not to scale.

The phone (voice) segment of the 80-meter band, referred to as 75 meters, is very popular as a medium-distance band and is good when you are not too far offshore. However, maritime operation is not permitted on that band, by International treaty. Incidently, I should clarify something here about maritime operation. The only time you should identify your Amateur station as "maritime mobile" is when you are in international waters. When you are within the coastal boundary of any country, you are portable or mobile within that jurisdiction. This includes rivers and coastal waterways and lakes.

There are many countries that permit Amateurs from other countries to operate within their territories; some grant a reciprocal permit, others allow an alien to acquire an Amateur license. If you plan to visit a foreign country and want to operate Amateur Radio there, you can often find out about the requirements from someone whom you talk to on the air. The American Radio Relay League, 225 Main Street, Newington, Connecticut 06111, has current information on license requirements and reciprocal agreements throughout the world. They can also advise you as to what governmental department to write to and approximately how long it might take to process the licensing paperwork. Write to the Membership Services department at the above address, and send a self-addressed, stamped envelope to speed up the reply.

How to get started

As I mentioned earlier, some of the sources which helped you find out about Amateur equipment will also be able to help you get started toward acquiring an Amateur License. The ham who told you where to buy a rig, or what brand was okay, will probably be able to tell you where in the area there are radio clubs. Many clubs conduct Amateur licensing classes, and if you can spare a few hours a month you have a good chance to earn a license between boating seasons. If you are not near any group or club that is holding classes, there are many excellent study guides available that you can use at home and some cassette tapes that will help you learn the Morse code.*

There will also be a series of Questions and Answer articles right here in *Horizons*, to help people prepare for Amateur license exams.

Don't let that code business get to you; it is just like learning a foreign language, but much simpler. There are no dialects to learn, no accents to practice, and no tongue-twisting combinations of letters and sounds. Further, Amateurs all over the world know the language, and you'll have no trouble conversing with them in the international "Q" code that is the radio operator's shorthand. The French Amateur you are talking to may not speak a word of English, but when you send QTR? (what is the correct time?) he'll know exactly what you want, and will reply QTR 2150Z (the time is 9:50 PM, at Greenwich).

So, there you have some of the reasons for taking Amateur Radio along with you on your next cruise, and a bit of information about how it is done. I'll be looking forward to hearing some new voices and calls from out on the blue water. Excuse me, I thought I just heard a familiar voice signing maritime mobile on my receiver. Let me turn up the volume a bit . . . "G5ANV this is K3RXK — Good afternoon, Rutger. It's good to hear your voice again. How is the race going, and is the wind treating you well? . . ." **HRH**

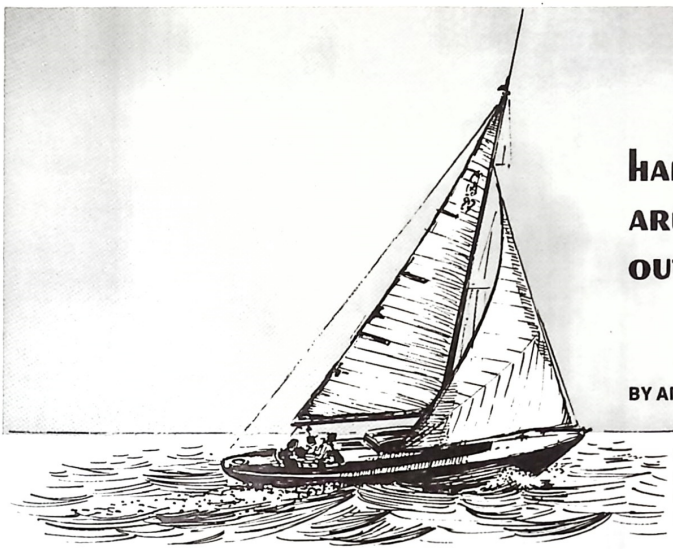
**ham radio's* Communications Bookstore has an excellent selection of study guide material and code-practice tapes. Write for the "I Want to Become a Ham" package, *Ham Radio Horizons*, Greenville, New Hampshire, 03048.

About the author

When it comes to marine communications, Herb Johnson, W6QKI, of Oceanside, California, is eminently qualified to cover all parts of the field. He has been in the electronics industry for better than 30 years, starting in the Great Lakes area where he and a partner became known for getting improved performance from some almost useless 10-watt transmitters of the day.

He was the founder, in 1961, of Swan Electronics, a manufacturer of Amateur equipment, which he sold to the Cubic Corporation in 1967. Not one to sit idly on the sidelines, he then founded Atlas Radio Incorporated, of Oceanside, California, where he is still involved in the design of modern state-of-the-art equipment for Amateur use. More than 10,000 Atlas transceivers have been sold, and many of them have found their way aboard boats of all kinds.

Herb has been sailing for better than 15 years, and has been involved in long-distance racing for the past 10 years. He can often be found aboard his *Vector*, a customized, 38-foot (11.6m) CF-37 sloop shown on our cover this month. The Amateur transceiver aboard *Vector*? A 7-pound (3.2kg) 200-watt Atlas, of course.



HAM RADIO SAILORS ARE NEVER OUT OF TOUCH

BY ANTHONY R. CURTIS, K3RXK

In fair weather, or foul, an Amateur Radio Station aboard your vessel is Bon Voyage

Ham radio operators in the southeastern corner of the United States were relaxing on a quiet Sunday afternoon last June, chatting with friends around the world and handling routine messages from hams aboard sailboats and ships thousands of miles away at sea in the Atlantic and Caribbean. Suddenly, an inexperienced-sounding voice on the air cried, "Mayday! Mayday!"

Quickly responding, hams learned that the yacht *Honeybee*, two days out of the Virgin Islands bound for the States, was in trouble. The captain had suffered a fatal heart attack, five landlubbers were aboard, and the vessel was rolling badly in heavy seas. Hams called the Coast Guard and activated Amateur Radio stations WB4SQJ at Miami and WB5KTY at New Orleans.

Following the terrified voices of *Honeybee* passengers on the 14-MHz ham band, direction-finding stations were able to pinpoint the exact location of the yacht. WB4SQJ and WB5KTY gave *Honeybee's* passengers careful step-by-step instructions, finally getting the boat turned around and headed for the nearest landfall on Grand Caicos Island.

A Canadian ham, listening in on the emergency from all the way out in British Columbia, switched to a different frequency in the 14-MHz ham band, made a call, raised George Thompson, operator of Amateur Radio station VP5GT on Grand Turk Island, and brought him over to the *Honeybee's* frequency. Familiar with both islands, VP5GT recommended bypassing the difficult anchorage at Grand Caicos and sailing on to Grand Turk where an easier landing could be made in the morning.

The drama continued through that Sunday night into Monday with a dozen Amateur Radio stations taking active part in the emergency communication. Hundreds of others stood by, monitoring the *Honeybee's* progress. The yacht's passengers, able only to use ham-radio gear, were connected (phone-patched) by hams into the United States telephone lines for calls to their families. They were also phone-patched to the sailboat's owner, the operator of ham station K2PSO, who had planned ahead for just such an emergency when he left a ham transmitter and receiver aboard *Honeybee*. He had left the rig tuned to 14.313 MHz where hams talk everyday with *maritime mobile* amateur radio stations at sea. The owner had instructed the novice crew to "turn it on and yell for help" if they got into any serious trouble. That made the rescue possible.

Fewer than 20 hours after the passengers sent the first *Mayday* call, VP5GT talked the *Honeybee* into Grand Turk harbor. Scores of hams in America breathed sighs of relief and tumbled into their racks for much-needed sleep.

As I bobbed along the Bay swells about 2300 GMT one evening last June and rested after a lengthy day-cruise, Rutger Webber, G5ANV, came back to my general call of

"CQ." Rutger, a member of the Hilbre, England, Yacht Club, was in the midst of a major Trans-Atlantic race to the Azores. He was on a rest break while under sail during the race.

Rutger and I talked for more than an hour and a quarter until 0017 GMT when he had to return to duty on deck. His signal from thousands of miles away across the Atlantic was loud and clear throughout. During our conversation, I learned that he grows strawberries near his Cornwall home, and that he works for the Commodore of the local yacht club.

The two greatest benefits of Amateur Radio afloat were wrapped up in that conversation with Rutger: Relaxation and safety. He was able to get away from stress to rest awhile. Clearly, if his crew had found trouble off France or Portugal, help could have been summoned easily through the ham gear aboard the racing yacht. If necessary, I could have used my radio equipment to span the miles back to Europe for help.

More drama on the high seas

In another recent incident, the 36-foot sailboat *Aburab*, owned by the Costa Rican operator of Amateur Radio station TI8FAG, was 200 miles west of Ecuador in the Pacific Ocean when a passenger came down with what appeared to be appendicitis.

TI8FAG fired up his ham rig on the 14-MHz Amateur band and contacted a ham radio club station at Fort Clayton, Canal Zone. The Canal Zone rescue center was notified, and dispatched C-130E aircraft with a surgeon and two paramedics aboard. Alan Biddle, operator of WA4SCA, Jacksonville, Fla., flew as co-pilot and radio operator of the C-130. Using the ham frequencies, WA4SCA was able to locate the *Aburab*. The paramedics were dropped to successfully treat the patient.

Not long ago, the *Kluanne*, a 31-foot Canadian sloop, was in distress off South Carolina's Atlantic coast. The operator of ham station VE0MCM aboard the sloop broke into a Sunday morning on-the-air-chat on the 4.0-MHz ham band between Earle Taylor, WA4CFX, Spartanburg, S. C., and a Florida station. They were joined by retired Coast Guardsman John Price, WB4JNK, Southport, N. C., who coordinated rescue efforts with the Coast Guard and the Federal Communications Commission (FCC).

The FCC officially declared the *Kluanne's* frequency available for use only in that emergency, since Amateur gear was the communications equipment available on the *Kluanne*. Sixty hams helped out on the air. Some 14 hours after

They may be masts to most yachtmen, but to an amateur radio operator they are also antenna supports. If you'll look close you can see an "egg" insulator in the backstay, near the top of the mast on K3RXK's *Freelance* (center foreground). A vhf whip antenna is located at the top of the mast, out of the picture in this view.

K3RXK checks into one of the nearby vhf repeaters through a hand-held transceiver. Because of the excellent location of repeaters, they can be reached by low-powered units operating near the water level at a range of several miles. The larger equipment on the desk is for use on the amateur hf bands, either voice (ssb) or Morse code.

initial contact with WA4CFX, the Coast Guard cutter *Reliance* was alongside *Kluanne*, and rescued its crew by sunset.

Operating a ham station aboard a boat or ship is easy; many amateurs do it every day. Saving life, limb, and property are obvious uses. Less obvious may be the countless hours of pleasure and relaxation, sprawling in a cabin or sunning on a deck, talking with friends near and far.

I spent six weeks last summer aboard my sailboat *Freelance*, sailing out of Annapolis, Maryland, on the Chesapeake Bay. From late May to early July, my nights were punctuated by the excitement of contacts with Willy in Ghent, Belgium; Joe on Swan Island; Bob in British Columbia; Joe in France; Vic in Grenada, Spain; Art in Munich, Germany; Leo in the Ukraine, USSR; Odon in Brazil; Elvio in Rome; Pat in Helsinki; Sam in Pointe-a-Pitre, Guadeloupe; George in Australia, and many, many more Amateur operators.

These conversations ranged from 10-minute exchanges of signal and weather reports to two-hour chats about local culture, sight-seeing opportunities, politics and other thought-provoking topics. My contacts were spiced by having a fellow yachtsman on the other end.

Talking with other boatmen who are not in distress is a great pleasure. I chatted with HP9XCD who, with his wife and two daughters, was aboard the 32-foot sailboat *Teachers Pet III* which, by his reckoning, was 450 miles north of Venezuela and 900 miles east of the Panama Canal. We didn't talk long, however, as he was looking for a western United States ham station to telephone friends back home.

Amateur radio is there when needed

Hams help anybody they can, not just private yachts. The 990-foot container vessel *Delta Mar* recently collided with the Liberian tanker *Alkus* 90 miles out of Galveston. The *Delta Mar* took heavy hull damage; its regular communications gear was knocked out. Bill Pearce, *Delta Mar's* radio officer and operator of his own ham station W0MWO at Pueblo, Colorado, called for help on the 7.0-MHz ham band. John Carlson, WA7SAU, Tucson, Arizona, and Bob Warriner, W5TT, Arlington, Texas, responded immediately.

W5TT, himself a former seafarer, took over relay chores for messages to the Coast Guard and to the *Delta Mar's* owners, while dozens of other hams stood by. After finally docking the *Delta Mar*, her captain telephoned W5TT to say, "Thank God for hams."

You'll find hams everywhere

A ham radio station aboard a boat can provide contact with just about any spot in the world. I regularly talk from *Freelance* to nearby hams in Maryland, Delaware, and Virginia as easily as with the continents of Europe, Africa, Asia, or Australia. In fact, during my recent six-week vacation, I chatted with hams in all 50 of the United States and on five continents. Of special interest to wanderers on the waves, most of the Caribbean Islands, including most out-of-the-way places like Cayman Island, Swan Island and even Serrana Bank, sometimes have active hams on the air.

Helpful hams at U. S. military bases seem to be everywhere including Gamboa, Canal Zone; San Jose, Costa Rica; and

Distance Conversions

31 feet	9.5 meters
32 feet	9.75 meters
36 feet	11 meters
990 feet	302 meters
10-15 miles	16-24 kilometers
50 miles	80.5 kilometers
90 miles	145 kilometers
150 miles	241 kilometers
200 miles	322 kilometers
450 miles	724 kilometers
900 miles	1448 kilometers

many other locations. There are hundreds of thousands of amateur radio operators in all walks of life around the globe.

Which radio should you have aboard?

Three kinds of two-way radio systems are available to boatsmen: Ham radio, Marine radio, and Citizens' band (CB) radio. Each system is distinctly different, and each requires a separate FCC license. Ham radio has many features that complement marine radio, while holding great advantages over CB radio.

Amateur radio

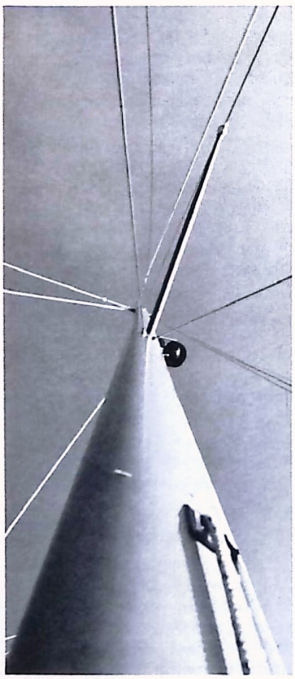
Hams use many different bands of frequencies in the radio spectrum, including short-wave, very-high-frequency (vhf), and ultra-high-frequency (uhf), bands that provide communications ranging from across a marina to across the world, any time of day or night. If they wish, Amateurs may operate transmitters with power up to 1000 watts into very elaborate signal-boosting antennas, and may indulge in chit-chat on any subject except money-making business matters. And, best of all for sailors, many Coast Guard stations have ham clubs monitoring for emergency calls on the Amateur frequencies.

Citizens' band radio

CB radios, on the other hand, are legally limited to only one short-wave band, and no vhf or uhf bands. A maximum permitted power input of 5 watts, somewhat restricted antennas, and a communication range limited to 150 miles, drastically curtails their usefulness. In practice, maximum communications range usually is not more than the equivalent of a few city blocks, and not more than about 10-15 miles in open countryside. The Coast Guard does not monitor or use CB radios.

Marine radios, of course, are monitored by the Coast Guard. The Marine Radio Service has two bands available for small boats: a 2-MHz short-wave band for use far offshore on the high seas, and a 156-MHz band for short-range contacts in and near harbors. Marine transmitter power on the 2-MHz band is limited to 150 watts: 30 times the power of CB sets. Meanwhile, the Amateur Radio power limit of 1000 watts is seven times greater than the marine radio power limit. The small ham short-wave radio I use aboard *Freelance* operates on six different short-wave bands and runs 140 watts. Marine radios on the vhf short-range band are limited to 25 watts, while hams enjoy a 1000-watt limit at vhf also.

The line going to the left from the top of the mast is really a backstay, insulated so that it can be used as an antenna for the high-frequency band amateur equipment aboard. The bottom end of the stay has another insulator, and is fastened near the transom area behind the steering wheel.



Marine radio

Boats outfitted for the 2-MHz marine band use antenna and ground systems similar to those used by hams operating in the six short-wave bands, and boats outfitted for the 156-MHz marine radio vhf band use antennas similar to vhf ham antennas.

Casual conversations are outlawed on the marine bands, so ham radio provides a back-up for vhf Marine Radio when a yachtsman is within line-of-sight-of shore, and for the 2-MHz Marine Radio when one is not too far offshore on "blue water." Ham radio also provides communication from points beyond the range of Coast Guard stations, and has the ability to reach directly to friends and relatives from thousands of miles away. The distance and reliability of Amateur Radio make CB radios seem mere toys.

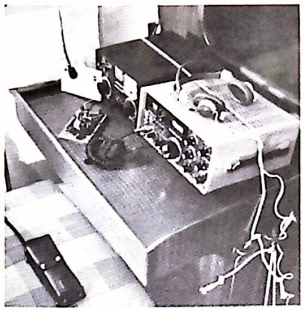
Ham radio is versatile

CB and Marine Radio Operators make only voice transmissions, whereas hams use voice plus International Morse code, television, facsimile, radioteletype and other, exotic, modes of communicating. Besides having great fun tapping out the dots and dashes of Morse code, hams know that code can be heard through static crashes which obliterate voice transmission.

Also much less power is required to get a code message through than is needed for a similar voice message, and a weak code signal can often be copied when a weak voice transmission is only an unintelligible whisper.

Licenses

It's not hard to get FCC licenses for any of these two-way radio services. Marine and CB licenses are yours when you complete an application form and plunk down the



The microphone and key are ready, the Amateur hf-band rigs are tied down in case of rough water, and the small vhf rig on the seat is ready to be clipped to a belt. Thus equipped, the *Freelance* is set for a weekend cruise with communications aboard for enjoyment or emergency.

required fee. Because it carries lots of extra advantages, the ham license requires passing a simple test of your knowledge of radio operating, FCC rules and the International Morse code.

The Federal Communications Commission makes licenses available to anyone passing the exam, regardless of age, sex, or nationality. U.S. citizenship is not required. Any person may take the exam and, if successful, receive Amateur Station and Operator licenses. Also, visitors from some other countries may operate Amateur stations here under reciprocal agreements between governments.

A good place to start

Paperback books giving questions and answers of the types asked on FCC exams are available from *Ham Radio Horizons* by calling toll-free (800) 258-5353 from 8 AM to 10 PM Eastern time Monday through Friday, and 8:30 AM to 4:30 PM on Saturdays. License manuals and study guides are available, along with code-practice tapes.

Learning the code is fun and not the stumbling block it might seem at first glance. Just last week, I talked on the air with a 12-year-old girl who had passed the ham-license exam and now is able to understand code sent at 15 words per minute. The beginning Novice-class license only requires sending and receiving five words per minute.

FM and repeaters

All CB and most marine radio communications are transmitted directly from one operator's set to another. Hams, on the other hand, have established a network of 2000 repeater stations across the United States, atop buildings, towers, and mountains, both inland and near seashores. Many other repeaters are in use in Canada and around the world.

Repeaters have very sensitive receivers and high-powered transmitters which pick up weak vhf voice signals and retransmit them over vast distances. Repeaters permit hams to talk far beyond the normal line-of-sight limitations on marine vhf radios.

Many Amateur operators have equipped their vhf radios with *Touch-Tone* telephone dials so they can make local telephone calls anytime to friends and authorities as if from an ordinary telephone. Police and other emergency services can be called from boat, car, or even deep in a forest. The telephoning ham need only be within range of a repeater.

I had an interesting conversation one evening last summer with Charlie, WA3RPU, as he was piloting the giant motorsteamer *Clipper* southbound in the large-ship channel of the Chesapeake Bay. Charlie had just left the port of Baltimore on his way down to Norfolk with a load of freight. We chatted for an hour before he passed out of range for direct boat-to-boat vhf communications. I was using only a small hand-held transceiver (transmitter and receiver in one box).

Freelance was rolling gently in her slip at Maryland Capital Yacht Club and I was relaxing on the port berth in the cabin with a cold *Diet Pepsi*. Saying goodbye to Charlie, I switched to a Baltimore repeater, and enjoyed a conversation with another sailor in his car 50 miles west of Baltimore on Interstate 70 heading for a weekend on the Bay. **HRH**

Glossary of Terms

Mayday is an International distress call, the voice equivalent of *SOS*; comes from French *M'aider* (help).

Landlubber is a person who is not used to sailing and ships.

Phone Patch is a device that can be connected between a radio and a telephone to permit telephone conversations to be sent and received by radio.

Paramedic is someone trained to give emergency medical treatment at the scene of a disaster or emergency.

Vhf is very high frequency, considered to be between 30 and 300 Megahertz.

Uhf is ultra-high frequency, considered to be between 300 Megahertz and 3 Gigahertz (3,000 Megahertz).

Blue water is an ocean or sea, as opposed to a lake or river; deep water.

Repeater is a transmitter and receiver combination, usually set up in a high, remote location, that automatically receives a signal, amplifies it, and re-transmits (repeats) it over a greater distance than would otherwise be possible.

Touch-Tone is a trade name by Bell Telephone Company for a push-button dialing system that produces a characteristic tone when a button is touched.

Introduction to the Propagation of Radio Waves

The transmission and reception of radio signals takes place by two basic modes — direct wave and sky-wave propagation. In this article you will learn the fundamentals of what, how, why, when and where to gain understanding

BY OAK OKLESHEN, W9RX

When you transmit or receive a radio signal by way of your station antenna, you may wonder how and why it all happens? Very simply, you can look at your antenna as a conversion device that transforms electrical energy from your transmitter into radio waves capable of travelling through space without wires. You can also look at your antenna as a device that converts radio waves from space into electrical energy that can be used by your receiver. Whether transmitting or receiving a signal, your antenna behaves in much the same way, only in reverse.

The transmitted wave leaves the antenna and travels by one or both of two basic methods. It can travel by *direct wave* — line of sight — or by *sky wave* — first by line of sight until it strikes ionized regions of gases in the earth's upper atmosphere, and then back to earth by reflection. These regions of ionized gases in the upper atmosphere are collectively called the *ionosphere*.

Until satellite and moonbounce communication became a reality, the direct wave was always called *ground* wave; but now the definition must be broadened to include any category that does not involve reflection from the ionosphere.

You can think of these two basic methods this way: Direct-wave transmission includes any method by which a radio wave travels from one point to another without making use of the ionosphere, and skywave transmission is any method by which a radio wave travels from one point to another by means of the ionosphere. Skywave transmission of radio signals is therefore referred to as *ionospheric propagation*.

Direct-wave transmission is easiest to understand, but to understand skywave transmission, it will be necessary to study the ionosphere in some detail. Future issues of *Ham Radio Horizons* will explore the subject of ionospheric propagation because it is still the most useful means for transmitting and receiving radio signals over long distances in the high frequency (hf) amateur bands with elementary equipment. Only frequencies between about 1.8 MHz (160-meter band) and 30 MHz (10 meter band) can be consistently transmitted via the ionosphere. Although the very high frequency (vhf) bands will occasionally make use of ionospheric propagation, the conditions under which this happens are very special and quite rare. Nevertheless, you will find presented here some explanation of how and when these special conditions may occur.

To begin, let's review what happens to the strength of radio signals as they travel along their skywave path from here to there. Compare a radio antenna with an ordinary light bulb. Just as the bulb is a source of light, the antenna is a source of radio energy. The farther away from the bulb you travel, the dimmer it appears, and the farther away from the antenna you travel, the weaker the signal seems. This is due to a law of physics called the *inverse square law* which says that the strength of a radio wave (or light) is inversely proportional to the square of the distance from the source. Let's see what this means in simple numbers. If you travel away from the antenna a distance of one mile (1.6km) and record the signal strengtf and then move two miles (3.2km) away from the antenna and measure the signal again, it will be only one-fourth as strong. Twice the distance — one-fourth the strength; four times the distance — one-sixteenth the strength; and so on. Each time, the strength is divided by the distance squared. This holds true under "ideal," that is, perfect conditions without taking any other factors into account. Nature is seldom "ideal," however, and usually many other factors must be considered. So it is with the transmission of radio signals by ground wave or skywave. Sometimes the signal is much stronger at the received end,

and sometimes it is much weaker, than the inverse square law would predict. Here's why.

When a ground wave signal is transmitted away from the antenna, part of it is usually absorbed by the surface of the earth or by objects in the signal's path. Sometimes just the opposite occurs, and a signal is "ducted," just as if it were passing through a tunnel or tube, being prevented from spreading out in all directions. In vhf propagation, a signal can be naturally ducted or tunneled by the effects of certain weather patterns and conditions in the lower part of the earth's atmosphere called the *troposphere*. The troposphere exists from the surface of the earth up to a distance of about six miles (10km). In another example — manmade this time — a signal is confined within a metal tube called a waveguide and is artificially conducted from its source to the point where it is received. This is something like a heater duct from your furnace conducting heat around your house, or a water pipe conducting water from its source to the point where it is used. Light is ducted in a laser beam because it is produced in such a way that it does not spread out like light from an ordinary bulb. Laser beams have been reflected from the moon using small amounts of power that, if used by an ordinary light source, would never even reach the lunar surface.

Radio antennas can be made to avoid the inverse square law to some extent by concentrating the radio waves in a narrow beam, thereby preventing them from spreading out as much as they normally would. Such antennas are called *beam* antennas, and many are used for TV and fm reception. You may have one . . . or more.

These are some of the reasons that the inverse square law does not always hold true in practice: Natural conditions occasionally "get around" the law, and manmade conditions can be provided to avoid it.

The Ionosphere

You have already learned that skywave propagation relies on the upper regions of the earth's atmosphere called the ionosphere. There is nothing very mysterious about this part of the atmosphere, except that it does have the ability to reflect radio signals. Do you wonder why that happens to only a part of the atmosphere? **Fig. 1** is a rough sketch showing only one region of the ionosphere for simplicity. Actually, there are three separate regions, or thick layers, called the D, E, and F ionized regions. Several short explanations are certainly in order. First, what happened to the A, B, and C regions? Simple; the discoverers thought that there might be other, lower, layers but weren't sure, and they didn't want to take a chance. Later, it was found out that lower layers did not exist, but the original names stuck.

Secondly, why are the layers there and how do they reflect radio signals? Amateur radio operators sometimes think of the ionosphere as being there for the exclusive purpose of aiding amateur communication, but this is really only a fringe benefit. The real reason for the existence of the ionosphere is because the sun emits ultraviolet and X-radiation, together with visible light. The ionosphere "traps" most of the undesirable or harmful radiation, allowing heat and light — necessary for life — to filter through. The trapped energy works on the gases in the upper part of the atmosphere, bombarding the molecules of oxygen, nitrogen, and some helium, causing them to *ionize*.

In their normal, quiet state, these gases have regular and predictable atomic and molecular structures. Each atom has a nucleus (positive charge) surrounded by orbital electrons (negative charge). These are the same electrons that flow in an ordinary electric current, except that they are tightly bound to atomic nuclei. When these atoms are struck by ultraviolet and X-rays, however, the electrons are driven farther away from their nuclei than normal, and the molecules, which are made up of strings, clumps and chains of atoms, become ionized. The nucleus of each atom no longer sees its orbital electrons close enough to remain neutral, so it separates into a positively charged entity called an ion and several negatively charged electrons.

If enough atoms are bombarded in this manner, the molecules are affected and

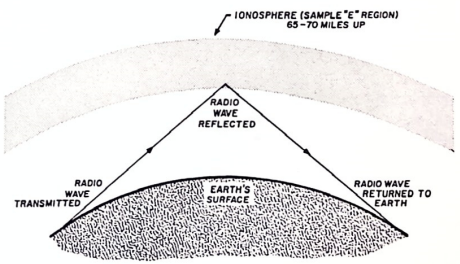


Fig. 1. A radio signal (sky wave) leaves the earth and travels to the ionosphere where it is reflected and returned to earth at a distant point. Although the ionosphere consists of several layers at different heights, the "E" layer is representative. The "D" layer is lower and the "F" layer is higher than the "E" layer, but all contribute to *ionospheric propagation*.

separation takes place. The gases are no longer in their normal state, but instead, become "clouds" of oppositely-charged particles from which radio waves are easily reflected. If the sun were to disappear for a day or two, the separated positive and negative particles would recombine, and typical atoms and molecules of the same gases would soon reform. Not all of the electrons return "home" however, and some of them remain free, particularly those of the oxygen atoms. Oxygen, stripped of its customary number of electrons, becomes ozo*ne*, which forms its own layer in the upper atmosphere. The ozone layer also shelters life on earth from harmful radiation.

As an illustration, a similar effect takes place on earth in an ordinary neon sign. Neon gas enclosed in a glass tube with an electrode at each end is excited by placing an electrical voltage across the tube, causing current to flow through the gas. Orbital electrons surrounding the nuclei of the neon atoms are driven farther away from the nuclei. When they try to "fall back" and return to their original positions, the released energy is given off as red-orange light, and the gas is said to be excited. It is possible that, if the ionosphere were pure neon, around-the-clock neon lighting from the sky would be visible all over the earth.

Continuous ionization and de-ionization takes place in the earth's atmosphere, with the ionosphere absorbing the sun's harmful rays. At night, less ionization takes place than during the day, causing the reflecting mirror for radio waves to become less reflective.

In future articles you'll read about the individual regions of the ionosphere in more detail, what happens to them, and how each affects radio communications in its own unusual way. **HRH**

TAKING THE MYSTERY OUT OF SINGLE SIDEBAND

Part 1

BY THOMAS McMULLEN, W1SL

You run into it everywhere — in the advertisements, in conversations with other electronics buffs, in engineering publications, — another addition to the endless alphabet soup terminology that people toss around so freely. The way the term is used you would expect it to be the cure of all times — the solution to the crowded frequencies, to interference, to the problem of getting a signal through when conditions are not so good — right? Well, maybe yes, maybe no; it depends on just how perfect a cure you are looking for.

Before I get further into the how of ssb, let me digress a moment to fill in a few notes about the background of ssb and the development.

The system of transmitting only part of the energy contained in a range of voice frequencies has been of interest to communications engineers for some time. It boils down to a basic premise that the wider a signal is (the more broad the range of frequencies used) the more likely it is to cause trouble to a neighboring channel. Early telephone systems used the brute-force method of transmission over long distances whereby the voice was amplified and passed along over the wires to the next station or amplifier. This was great for one-way transmission, but people like to talk back and forth without having to throw a switch to change the direction of information flow. It is difficult to make an amplifier work in both directions at once, and double lines would be prohibitively expensive. The solution was to use a radio-frequency signal as a carrier, modulating it with the voice content, and to amplify the carrier at the proper intervals along the way. By the proper selection of filters and tuned circuitry, two or more carriers could be sent along the same wire or cable. It wasn't long before the increased demand for telephone and message services began to overload the system, causing the economy-minded planners to start asking for some way to avoid stringing more cables to meet the need. The answer was to make the carrier work harder — since one of the sidebands was a mirror-image duplicate of the other, why not get rid of it and replace it with something useful like another sideband that bore no relation to the other.

Thus commercial interests developed ssb transmission techniques and hardware quite some time ago — back in the early '30s — and have been using it (with variations) since then. It was not adopted by the Amateur Radio fraternity for several reasons, the chief one being that the equipment then available was very expensive, little understood by those outside the business of communications, and quite specialized for the purpose intended.

Even after the equipment became more available and less complex, the mode was not welcomed with open arms by amateurs, who had an understandable reluctance to switch from their "high-fidelity" (but inefficient) a-m rigs to something that sounded somewhat like a cross between a duck speaking a foreign language and a transmitter with an intermittent final amplifier tube. The receiving equipment available at that early stage of amateur involvement did little to help the situation either — proper tuning-in of an ssb signal required accuracy to a degree of a few cycles (yes, they were still called cycles then) but the old beloved receivers could drift several hundred cycles just from the after-effects of someone sneezing in the same room with them!

Things gradually improved, thanks to efforts of some stalwart pioneers who could see the many advantages (and the handwriting on the wall) and kept up the educational efforts until the features of the new mode became clear to an increasing majority of amateurs.

Some of the farsighted equipment manufacturers did their share to promote the growth of this new mode of amateur communications by developing and marketing

transmitting and receiving units that made it as easy to tune in ssb as it had been to work with a-m. The durability of some of the equipment speaks well for the design — many of the units are more than 20 years old and still going strong.

What's this carrier thing?

The full terminology that goes with the letters ssb is Single Sideband, Suppressed Carrier, and early attempts to alphabetize it did indeed use the full SSSC designation. While descriptive, it was difficult to say and definitely non-euphoneous! By abbreviating the abbreviation, the term ssb, for single-sideband, came into general usage. Now, I've told you what the letters stand for, but you still want to know what it means, right?

Ok, let's pry a little farther into the mystery. In order to understand why we can do without a carrier, I'll have to tell you why a carrier is needed in the first place. (Sounds like the tactics of some bureaucrat — convince you that you need something, and then take it away from you.) Just as in the early days of telephone line, you could get your voice from one place to another by simply amplifying it and passing it along, but it would take a monstrous amplifier and speaker system, and the noise pollution would be sure to raise the hackles of every environmentalist (and everyone else) in the neighborhood. Talk about a headache!

So once again technology comes to the rescue by providing one signal at a high-frequency which can have the information (voice) signal impressed on it. Because the high-frequency signal is way above the hearing range of everyone, it can go zipping through the quietest of neighborhoods with no one the wiser. This high-frequency signal is in the range that we call *radio frequencies*, and since it carries your voice along with it as it goes, it is naturally enough called a *carrier*.

Sidebands?

Ahhh . . . Um . . . yes, sidebands — I was afraid you would ask that. Just in case it isn't obvious, let me point out that your voice is not just a single frequency, but rather a mixture of many frequencies in combination and at varying degrees of loudness. Therefore a voice can be said to encompass a range or *band* of frequencies. This band of frequencies is in what we call the audio (or audible) range, which starts somewhere below 100 hertz (cycles-per-second) and extends upward to several thousand hertz.

But for purposes of clarity. I'll pick out a single frequency (2000 Hz) in the audio range and use it in the following explanation of how the carrier does its thing.

The process of impressing the audio information on the carrier is called modulation. According to the dictionary, to modulate means to adjust or adapt to a certain proportion; to vary the pitch, tone, or intensity; or (electronics) to vary the frequency, amplitude, phase, or other characteristic of (any carrier wave). Well, now, since things started out as amplitude modulation (a-m) you would expect that the result of all this would be to have the carrier bobbling up and down in strength in accordance with the voice information that you applied to it, right?

Well . . .yeah, it does, but not to any extent that you would find very useful. The most important product of the modulation process is really the result of a mixing action more than anything else. Mixing, is radio terms, is much like mixing anywhere else. You can mix so many parts of A with so many parts of B, and the result is so many parts of C (1 part of red plus 1 part of yellow equals orange).

So let's see what happens when you mix a couple of frequencies together, and to make it easier to follow the numbers around, let's use 100,000 Hz as a carrier and 2,000 as the voice frequency (hello, squeaky!). The carrier frequency could be abbreviated to 100 kHz, but numbers are impressive, so we'll keep the whole thing. The most obvious product of mixing these two is that you now have an output at 102,000 Hz (100,000 + 2,000 = 102,000). Right about here is where things get tricky, and you can forget about the paint store; there is also a product of the subtraction process, which

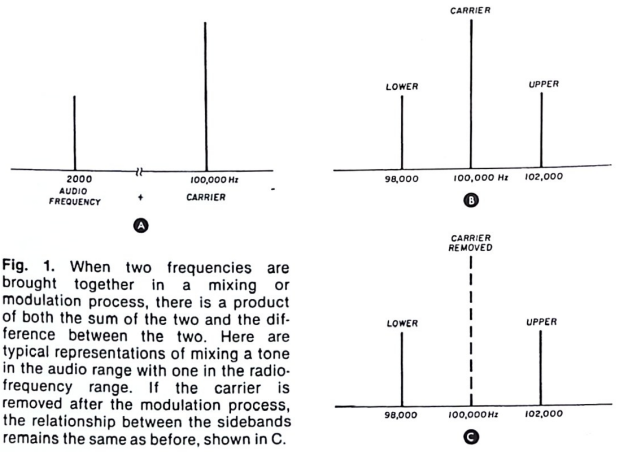


Fig. 1. When two frequencies are brought together in a mixing or modulation process, there is a product of both the sum of the two and the difference between the two. Here are typical representations of mixing a tone in the audio range with one in the radio-frequency range. If the carrier is removed after the modulation process, the relationship between the sidebands remains the same as before, shown in C.

is the *difference* between the two frequencies! And for all intents and purposes it is happening at the same time as the addition is being done. (For the time being, don't worry about *how* it happens; it has to do with phase angles and current flow within the mixing device, and can be explained with the use of some pretty impressive mathematics, so don't ask me any embarrassing questions. Okay?) As I said, 100,000 – 2,000 = 98,000 Hz. This is illustrated graphically in **Fig. 1**, which is just the way you would find things if you had a very good receiver and could tune across that part of the radio-frequency spectrum. There are devices, called spectrum analyzers, that can do just this and display the signals picked up on a screen so that you can actually see the relationships involved. There is a direct proportion between the amount of energy (loudness) in the 2,000 Hz signal and the strength of the 98,000 and 102,000 Hz products. Obviously if you reduced the voice signal to zero, the products would go away, and if you increased the strength of the signal the products would get stronger — up to the point at which the system became overloaded. (It's red-lined at 100%, which means that is as far as it will go without undesirable things happening). At 100-per cent modulation, the amplitude (strength) of both the sum and difference products will be just half that of the original carrier. Yes, it is possible to make them more and half as strong, but when they get that large, they tend to feel pretty self-important, and do a little mixing (modulating) of their own, which produces further sum and difference products, (96,000 and 104,000 Hz, for instance) which is not exactly what we had in mind.

So, there you have it. A carrier is mixed with the signal (information) frequencies, and launched into space, to eventually find its way into your receiver, still carrying the information along with it. In your receiver you have a detector (demodulator) circuit that sorts out the signal and carrier frequencies, and applies the signal to a headset or loudspeaker so that you can hear it as a faithful reproduction of the original.

But it is a little difficult to speak (or understand) a single frequency, so it is rather convenient that the carrier is capable of handling a pretty good range of audio frequencies all at once. If you had a receiver that would tune in a carrier that was modulated with the voice-range of frequencies, you would find that it resembled that in **Fig. 2.** You would see the carrier standing tall the same as before, and it would have the sum and difference frequencies keeping it company. That part of your voice that was in the lower range would be closest to the carrier and the higher tones would be farther away. These bands of frequencies appear on either side of the carrier, and hence are called *sidebands* (thought I would never get there, didn't you?)

Single, sideband, suppressed carrier?

Not so faaaast — one thing at a time there! To answer your last question first, let's take a look at the carrier and why we can get rid of it (and more importantly, why we should want to).

Just in case you missed the point earlier, I say again, the carrier is a single frequency in the range that we call radio frequencies (because you can tune them in on your radio, why else?). The example that we have used is 100,000 Hz. Now just suppose that someone up the street a bit decides to have a carrier too, and further suppose that he picks 101,000 Hz. He can transmit his carrier in any direction he wants, and you can do likewise. The two carriers don't bother each other at all — coexistence is a happy thing. But when they both get into your receiver, — look out! Receivers are full of devices that can and do perform the mixing (modulating) function with great gusto. In fact, several of the stages are designed to do just that. So,

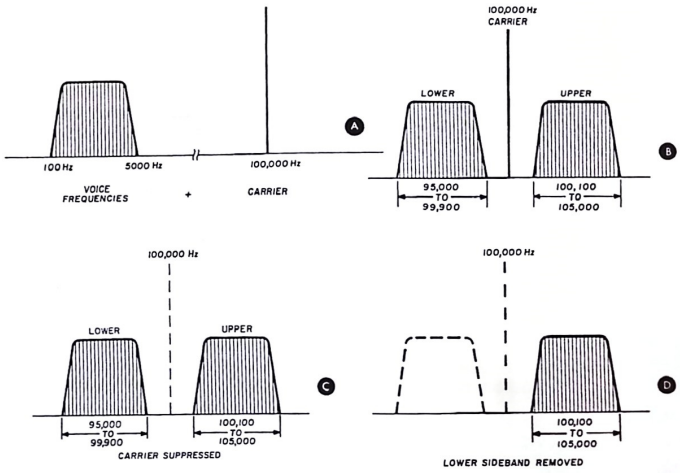


Fig. 2. When a range of frequencies, such as that found in the human voice, is used instead of a single tone, the result of the modulation process shows the carrier with "bands" of frequencies on either side. To obtain single-sideband-suppressed-carrier, it is necessary only to remove the carrier and one sideband.

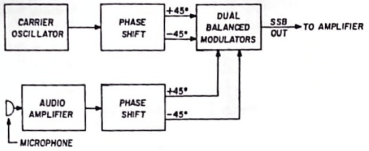


Fig. 3. A block diagram of the essential portions of a phasing type of ssb generator shows that some tricky application of phase shift is required for both the audio and the radio frequency. The carrier and one sideband are removed, leaving only one sideband at the output. This remaining sideband can be amplified and further processed to make it useful for communications purposes.

look at the numbers again and remember what we said about the mixing products before. 100,000 + 101,000 = 201,000 Hz. What? Yeah, I know it is above your hearing range but you didn't let me finish. 101,000 *minus* 100,000 = 1,000 Hz and you can sure hear that. That is exactly the process that produces all of those whistles and squeals that you hear when two or more a-m carriers get together. If you haven't heard them you just haven't ever turned on a CB receiver. There used to be a lot of them on the amateur bands too, before ssb caught on.

A couple of things suggest themselves here. If you will look again at **Fig. 1** you'll note that the carrier is the biggest (strongest) thing there, so it follows that the carriers are creating the strongest difference frequency (which we can call a beat-note, or to use the colloquial term "heterodyne"). Therefore it also follows that if you get rid of one of the carriers you will get rid of the heterodyne, right? Very true, but it might be just as hard to talk your neighbor into turning his off as it would be for him to convince you to turn yours off. So the thing to do is for both of you to get rid of the carriers — exit heterodynes.

There, now you know why.

How?

I'll get into the grimy details of exactly how it is done and what circuits are required to accomplish removing the carrier at a later date. But to boil it down to a few words, you make it cancel itself. This electronics business is full of interesting terms such as phase and amplitude (no, it doesn't have anything to do with the moon). By running the carrier through the proper maze... uh, circuitry, it can be split up into two phases, and if the two are exactly opposite they cancel each other. Sort of runs into itself coming around the corner and — blooey! The tricky part is that you can apply the signal (voice) frequencies in such a manner that this doesn't happen to them — in fact they usually come out of the modulator in such a relationship that they help each other. This is called the *phasing* type of generator (not phas*or*, phas*ing* — you Star Trekkies). An essential part of this generator is called a *balanced modulator,* which tricks the carrier into cancelling itself. Without even pausing for breath, let me point out that there are two ways to get rid of one sideband. The first is to add refinement to that phasing circuit that I just told you about: If the phase of the *audio* frequency is shifted a bit before you apply it to the modulator, then the same phase shift that cancels the carrier also changes the signal (voice) phase in such a fashion, that one sideband does not get cancelled.

A look at **Figs. 2** and **3** will reveal that a bit more clearly. The carrier at 100,000 Hz has been cancelled, so it is no longer there. A phase shift was applied to the audio signal, so, that one is cancelled and one remains — in this example the *upper* sideband. It works exactly the same way if we want to retain the lower sideband, it just takes a little bit different path through the circuitry so that the phases get shifted in the right direction.

A second method is called the *filter* system of ssb. generation (**Fig. 4**). One thing that the filter type of generator has in common with the phasing type is that it too requires a balanced modulator. Remember that the balanced modulator is the essential circuit that gets rid of the carrier, leaving the sidebands. In this type of generator a filter is used that will allow only the proper sideband to get through. In its most simple form, a filter would be a resonant circuit that was adjusted to 102,000 Hz. Actually, such a basic filter would not be completely effective in getting rid of the unwanted sideband, so a more complicated version is used. **Fig. 5** illustrates the properties of filters that are needed for this function. Filters can be made up of many resonant circuits in the form of inductance and capacitance, or

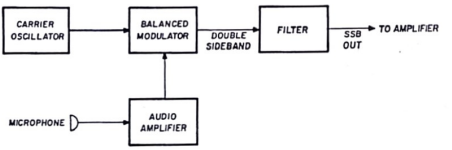


Fig. 4. A filter type of ssb generator appears to be simpler to build and work with. Actually, it will require more processing later on to obtain sideband output on the proper frequency. This processing is termed "heterodyning," and in spite of the additional stages required, is one of the most popular types of transmitter used for communications today.

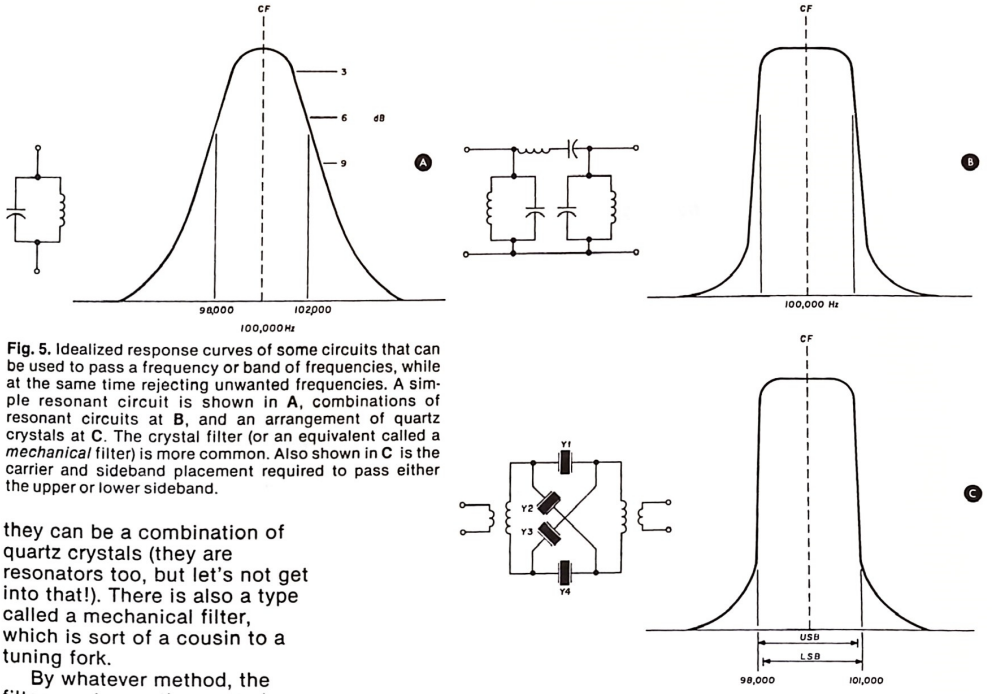


Fig. 5. Idealized response curves of some circuits that can be used to pass a frequency or band of frequencies, while at the same time rejecting unwanted frequencies. A simple resonant circuit is shown in **A**, combinations of resonant circuits at **B**, and an arrangement of quartz crystals at **C**. The crystal filter (or an equivalent called a *mechanical* filter) is more common. Also shown in **C** is the carrier and sideband placement required to pass either the upper or lower sideband.

they can be a combination of quartz crystals (they are resonators too, but let's not get into that!). There is also a type called a mechanical filter, which is sort of a cousin to a tuning fork.

By whatever method, the filter must pass the wanted sideband and keep the unwanted one from getting through. At first glance it would seem that you would need two filters; one for the upper sideband and another if you wanted to use the lower sideband. But, no, filters are just a bit expensive, so there must be a better way. There is, and it is so simple that I wonder that I didn't mention it before: All you have to do is move the carrier. That is easy. A carrier can be generated by an oscillator that is either variable or is fixed in frequency by a crystal. If you change the frequency of the oscillator so that it is no longer at 100,000 Hz, but is somewhat lower — say 99,000 Hz, then you have plunked the upper sideband right in the middle of the filter. Conversely, if you want to use the lower sideband, then you move the carrier up a bit, to perhaps 101,000 Hz, which then places the lower sideband in the window... er, filter.

Only one sideband?

Oh, yes, the reason for using only one sideband is really rather easy. All of the voice frequencies that you transmit are contained in both sidebands, so if you tune in to just one of them you will still hear every word. Look back at **Fig. 1** again. Remember that your receiver translates the sideband (98,000 Hz or 102,000 Hz back into the original 2,000 Hz that you started out with, so you could tune in to either one and hear the same 2,000 Hz tone; it's the same with voice. So if everything you need to hear is contained in just one sideband, why leave the other tag-along flopping around in mid air, with no one listening to him? Besides it takes power to transmit sidebands, and the power you don't use for the lower can be applied to helping the upper. (Or to express it so Mother Earth will love you, you are saving half the power by only sending one sideband.) Clear enough?

So there you have it. By getting rid of the carrier you eliminate most of the whistles and squeals that plague a-m operation. By using only one sideband you save space on the band, conserve power, and allow room for another operator to sneak in close to you without causing trouble and interference. Ssb may not cure *all* of the troubles in the communications world, but it will surely help to make life a lot easier.

Receiving SSB?

Hold it! Let's not get carried away. I'm saving that (and a few other goodies) for next time. **HRH**

SINGLE SIDEBAND

Part 2

A sideband receiver must have some special circuits to turn the signal into something you like to hear

BY THOMAS McMULLEN, W1SL

During the last session when we talked about ssb there was great to-do about getting rid of the carrier, and what the benefits were — chiefly the reduction of heterodyne tones and less interference. Well, now it's time to talk about receiving sideband, and I'm going to give you a little hint about how it is done: You have to put the carrier back.

Yep, that's right, after going to all that trouble to get rid of it, the receiver has to put it back if what you hear is to sound like what the guy at the other end is saying. But in order to paint a clear picture, I'll have to go back over some basic theory — like rectification of alternating current (ac). Radio-frequency waves *are* ac, and can be treated just like any other alternating current so long as you remember that the power is considerably lower than what comes out of your wall socket, and that the frequency is much, much, higher. For instance, if you have a house circuit that is protected with a 10-ampere fuse in a 120-volt circuit, you can use up to almost 1200 watts before the fuse goes away. By contrast, the voltage at the input to your receiver, even when you are listening to a guy on the other side of town who has a "bodacious" signal, is likely to be on the order of 0.002 volt! For the purpose of figuring how much power that is (so we'll not be comparing apples and bowling balls) let's assume that the input of your receiver is 75 ohms (some are and some are not). Going back to a law attributed to some guy named Ohm, we can see that Power = voltage squared divided by resistance:

$$0.002 \times 0.002 = 0.000004 \div 75 = 0.000000053333 \text{ watt}$$

That surely is not much power, so it has to be handled with care or you'll lose it. (I wish I had picked another example so it would come out even! Oh, well.)

So, back to the basics: Rectification. Detection in a receiver, such as the one you use to listen to your preferred music, is accomplished by simple rectification and filtering, just like a power supply. No, no, not fm, a-m (amplitude modulation) like I explained for the modulation process in the first place. Fm is a whole different bag of worms. In **Fig. 1** I have shown the result of applying ac to a rectifier, and how a filter smooths the dc output. It is following the same principle that a power supply does — a diode allows current to pass in one direction only, and a capacitor stores the energy and eventually smooths the output to a somewhat constant level.

Now things get a bit more complicated when the ac has some form of amplitude modulation impressed on it. The main part (the carrier) is the largest, and most steady, but it is accompanied by the sidebands which are slightly different in frequency and are changing strength in accordance with the modulation (voice or tone).

Let's see if I can go through this slowly so you can follow. In **Fig. 1** I used an example of 10 volts ac applied to the rectifier to obtain a dc voltage of 4.5 V. (This time I'm using numbers that work out without all those 3s hanging off the end). It follows that if I increase the voltage to 20, then the dc output will also increase — in this case to 9 V. This follows well defined principles that can be found in almost any basic electronics text. To sum up: The application of a varying ac voltage to a rectifier will produce a varying dc voltage at the output. Sound good so far? Right!

Okay, remember what I said about the carrier and its sidebands? It is a somewhat constant ac voltage accompanied by a varying ac voltage — which leads right to the point that the application of this voltage to a rectifier will *also* produce a varying dc voltage! This is shown in **Fig. 2**. There's a little trick here that I'll point out just so it will not sneak by unnoticed. The ac voltage (rf) is varying in amplitude *at an audio rate*. You can see in the drawing (**Fig. 2A**) that the lines inside the "envelope" are closely spaced, but that the envelope has the appearance of a double sine wave. This sine wave (modulation) is varying the height of the higher frequency component at the same rate as was applied to the modulator (2000 hertz if I remember correctly). It has exactly the same effect as if you had a potentiometer (voltage controller) hooked up to the rectifier and were turning the knob back and forth. It causes the dc output to vary at an audio rate: 2000 Hz.

Filtering? Um . . . yeah, I follow what you are asking. Doesn't the capacitor that filters (smooths) the output get

rid of the audio? Nope! Not if you do it right. There is a little plotting and planning involved here, too. Somewhere I remember reading that capacitors have reactance (which is another way of saying that the resistance varies according to the frequency applied). Therefore it should be possible to find the right value of capacitance that would be a very low resistance for the high-frequency (rf) ac component, but has very little effect on the audio-frequency part. That's exactly what happens. A value of 0.05 μF has a reactance of 31 ohms at 100,000 Hz, but at 2000 Hz it appears to be 1600 ohms. The result is that the carrier is faced with what appears to be a near short-circuit and that is the end of that. The audio, on the other hand, looks at a much higher resistance and gets by without too much of a struggle. So, there, we've done it —

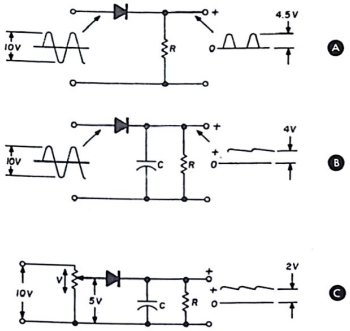


Fig. 1. The most common detector circuits in receivers are very similar to a rectifier that is used to turc ac to dc. In **A** the alternating current is applied to a rectifier, which conducts on the positive portion of the cycle. The output has no filtering (smoothing), so the resultant waveform is a series of "peaks" rising above the zero-voltage baseline. At **B** the same input waveform is applied, but the output circuit has a capacitor, **C**, to act as a smoothing filter. The waveform from this simple filter is dc with slight bumps on it where the capacitor is recharged by the rectifying action of the diode. At **C** the input amplitude is made variable, simulating a received signal that is varying in strength. The output is still "lumpy" dc, and its magnitude varies in proportion to the input.

removed the carrier and left the original audio to be amplified and applied to your ears.

No-carrier detection

Well, now that we have struggled through all that razzmatazz about detection of a signal that has a carrier attached to it, perhaps we can get into how to handle something that has no carrier. In one of the illustrations with the first part of this article, the sideband was finally isolated and standing all by itself at a frequency of 102,000 hertz. So let's assume that this signal finds its way to your receiver, and through the various amplifier stages inside it, and finally winds up at the detector (rectifier) just like any other ac voltage. There it is, 102,000 hertz, going into the diode, turning it on every half cycle, and dashing pell-mell into the filter at the output of the diode. The result? You get a dc-voltage output just like that shown in **Fig. 1B**! Not much percentage in that, is there? The object was to recover the audio that started this whole thing in the first place — the guy at the other end speaking into a microphone (or sending a 2000-Hz tone, to be true to our example).

Aha! Now is the time to put the carrier back in its rightful place. Look at **Fig. 3**. Seem familiar? It should because it is similar to **Fig. 1** in part one of this dissertation. If the carrier is placed just 2000 Hz below the upper sideband signal (and we will assume that we *are* talking about the upper sideband here), both important elements are back in the picture again — a carrier at 100,000 hertz and a sideband at 102,000 hertz. The diode (rectifier) is also a neat little mixing (modulating) device, and as such proceeds to mix the two frequencies in fine shape. The sum product of the two (202,000 Hz) is very easily shunted out of the picture by the filter capacitor after the diode, which leaves the difference product — yep, 2000 Hz — to follow the same path out of the detector as did the audio component in the previous example (**Fig. 2B**).

Getting the carrier

How do you get a carrier if the station at the other end didn't send it? Had the answer right on the tip of my typewriter . . . you just include an oscillator in the circuitry. If you make it just like the one at the transmitter end, it should provide the same carrier for your receiver as his did for the transmitter. Well, almost. You have to take into account the fact that most radio equipment is not that stable — temperature, voltage, adjustments — all of these can cause a given oscillator to be slightly different from one that is seemingly identical. Since we want the audio to be 2000 hertz and not 1980 or 2050 hertz, or whatever, the local carrier must be at the right spot with relation to the sideband. This is easily taken care of by making the oscillator variable over a small range. If the oscillator can be tuned from 99,000 to 101,000 hertz, then it is easy to see that somewhere between those two limits there is a spot where it is exactly right to hear the audio at its proper pitch. A smooth tuning control will make it duck soup . . . ah, very easy to tune in the signal by ear until it sounds right. This is especially true when you are listening to the human voice, since you have a general idea of what to expect.

Placing the local carrier in the right spot also makes it easy to recover the voice range of frequencies — the lowest tones will be near the carrier and the higher ones will be farther away, just as they were in the transmitter example.

Remember the trick used to obtain either upper or lower sideband? The one about moving the carrier to one side or the other? It works here, too. Obviously if you placed the carrier on the wrong side of the

voice sideband, and had the higher frequencies nearest the carrier, and the lower ones farther away, the voice would come out upside down (**Fig. 4**). I kid you not, that is what happens, and it sure sounds weird. Matter-of fact, that is one simple and basic form of speech scrambling. It was used by some businesses that have shortwave circuits for telephones to various places around the world. Don't think that you can go tuning around and "descramble" some hot conversations, though! They have added some other tricks to make life difficult for us snoops.

Of course it is not absolutely essential that the local carrier oscillator be variable in frequency — it can be crystal controlled, and many of them are. This makes switching from upper to lower sideband a snap — literally — by changing from one crystal to another. Incidentally, the oscillator that I have been talking about for generating the carrier is called the bfo (beat-frequency oscillator). It got that moniker in the early days of receiving Morse code signals, when it was used to beat against the signal to produce an audio tone. That's as good a term for it as any.

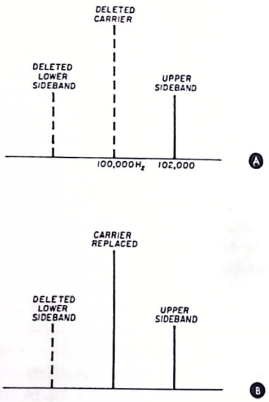


Fig. 3. To properly detect a sideband, the detector must "see" two components — the sideband which varies at an audio rate, and a carrier. The carrier must be generated with the proper frequency relationship to the sideband, as shown at **B**.

Detector types

So far, I have been talking about a rather simple diode type of detector, which will work for a-m, ssb, or CW. It does its job, but there are problems with it. One is that the amount of audio recovered is somewhat low; another is that the presence of the carrier, forcing a current flow through the diode, creates noise. Now, noise is something that you don't need, and inefficiency you can do without, too. Other people felt the same way, and developed a better detector. It's called a *product detector.* It is called that because it produces an output that is the product of two inputs. Describe it? Well, lets see . . .

Fig. 5 is a good place to start. There you see something that bears a striking resemblance to the diode detector used as an example before. Since there is no carrier being applied to the diode from the amplifier circuit, one must be fed to the diode from a local source. This source is called, appropriately enough, a carrier generator. It is almost indistinguishable from the beat-frequency mentioned earlier. This is a crude type of ssb detector, but it does work. It requires better circuitry to give better performance, and **Fig. 6** shows an improved product detector. Here you make use of a principle that was touched on in the generation of ssb — the balanced modulator. The carrier is applied to the diodes through the transformer in such a manner that it virtually cancels itself after doing its job, which is to turn the diodes on and off at a very rapid rate. The sidebands, from the amplifier stage, are applied to the diodes in a way that allows them to beat (heterodyne) with the carrier, and the difference (product) is left over to be connected to an amplifier.

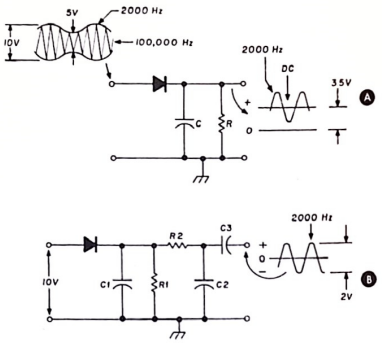


Fig. 2. When the input waveform to a rectifier (detector) is complex, the output waveform is also complex. The high-frequency part of the input is rectified and smoothed by **C**, which creates a dc component. The low-frequency portion of the input is passed through the rectifier, and, because the capacitor is not large enough to have an effect at the low frequency, causes an audio-rate variation of the dc level at the output. At **B** an additional filter consisting of R2 and C2, and an isolating capacitor, C3, removes the dc component and allows only the audio to pass. At this point the audio should be a reasonable duplicate of the audio that was transmitted by the other station.

There are filtering capacitors connected with this type of detector, too, but they are not required to do nearly as much work because the amount of carrier left over after the detector is negligible. The product detector is great for ssb and CW, but is rather a nuisance for amplitude modulation because the local carrier must tussle with the carrier that is coming into your receiver along with the modulation. To properly receive a-m, you must adjust the carrier oscillator until it is exactly zero-beat (no frequency difference) with the incoming carrier. Two carriers tend to overwhelm the sidebands, and consequently the amount of audio recovered is lower than desired. However, it will work, so don't figure that you will never be able to listen to a-m again.

There are many other arrangements of product detectors, some involving

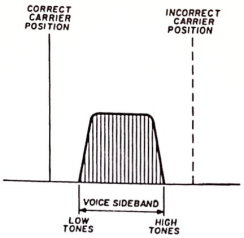


Fig. 4. When a band of frequencies, such as in a voice, are to be received, the frequency relationship is of prime importance. If the carrier is placed on the wrong side of the voice band, the voice will be inverted, causing the high and low tones to exchange places. This same relationship must be observed throughout the ssb system — transmitters as well as receivers.

specialized tubes, and a couple of recent ones that use a specialized (and very complicated) integrated circuit. No matter what the device, they all involve the same principle: Causing a mixing or heterodyning between the incoming sideband and the local carrier.

Amateur frequencies

Up until now, I have used the example of 100,000 hertz for the carrier frequency. That was mainly because it was a nice sounding number with a lot of zeroes that would impress people. It is also less than a billion, so no one could confuse it with a government spending program. Now, I'm afraid that we'll have to face life and journey into the real world. There are no amateur frequencies at 100,000 hertz.

But you know that ssb works as much higher frequencies — you have heard them there. From 1.8 MHz (160 meters) to 30, or even 1296 MHz, amateurs are using ssb and enjoying it. Some equipment for 27-MHz CB use has ssb capabilities too. How does it get there?

Again, the good ole standby — heterodyne — comes to the rescue. This time I'll make use of the sum product of the mixing process. One of the fortunate results of this type of mixing is that things tend to stay right-side-up, so that the voices do not come out inverted as I mentioned earlier when I pointed out what happened if you put the carrier in the wrong place.

The amateur 21-MHz (15-meter) band is as good a place as any to start. Let's assume that you want to generate a sideband signal at a frequency of 21.4 MHz. That's twenty-one million, four-hundred thousand hertz, but there is no point in waving *that* many zeroes around! M is the abbreviation for million, and the term MHz is pronounced megahertz.

It will make things a lot easier if you keep the sideband that was generated at 102,000 Hz as a starting point to get to the higher frequency.

Fig. 7 shows what happens if two frequencies are added together in a mixing scheme. It is much the same as what happened earlier in generating a sideband signal, except that the frequencies are much different. You really don't need a drawing to figure this one out

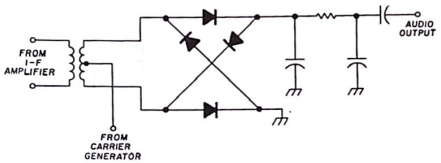


Fig. 6. An improved ssb detector makes use of the balanced modulator (mixer) type of circuit. Again, the i-f stage supplies the signal (after being amplified by previous stages) and the carrier generator provides a carrier with the proper frequency relationship to the sideband being received. This "balanced demodulator" is more efficient than the simple rectifier type.

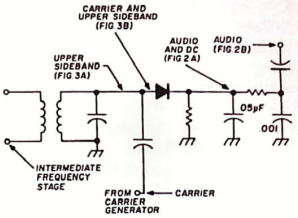


Fig. 5. A simple type of ssb detector is merely a rectifier circuit that obtains one signal from the i-f stage, and another from the carrier generator.

though — you can simply add up the numbers: 21.298 + 0.102 = 21.400 MHz. Simple enough! Oh, yeah — that 0.102 is the same as 102,000 hertz. Okay?

So, now you have the same sideband that you started out with at 102,000 hertz, and it is perfectly happy to be bouncing around up there at 21.4 MHz as an upper-sideband signal among the rest of the crowd. Problem is, how do you detect it? No, you cannot just feed it into an amplifier and product detector that are built to work at that frequency. Well, you could — in theory — but it is not so easy in practice. Remember I told you that the signal at the input of the receiver would be pretty weak, which means that you need some very good amplifiers to build it up to something useful. Amplifiers like that can be built, but there is a catch. You need a local carrier for the product detector, right? And it must be at a frequency of 21.398 MHz, right? (Remember that the sideband you want to hear is really a 2000-Hz tone in disguise, therefore the carrier must be 2000 Hz below it to be in the proper place: 21.4 − 0.002 = 21.398 MHz.) To make the product detector work properly, the carrier must be strong — from a half a volt to perhaps 2 or 3 volts. Here's the clinker — there is just no way that your amplifier is going to ignore that 2-volt carrier in the same box with it and amplify that 0.002-volt signal from across town!

It's going to make like that proverbial snake that swallowed its own tail and lock itself up in a tight loop which is totally useless!

To the rescue

It may seem that this heterodyne guy is hogging the show at this point, but face it — he's indispensible. So, here we go again. Put an amplifier or two in the system, tuned to 21.4 MHz (**Fig. 8**). Okay, now the sideband signal is boosted up a bit, it is not so likely to get lost in a resistor or something. Next comes a mixer that is almost a duplicate of the one
that was used to generate the 21-MHz signal before. It works with the same numbers too: 21.4 − 21.298 = 0.102 MHz, which is the same as the 102,000 hertz that we had in the first place (but it doesn't really *have* to be, modern receivers use frequencies from 50 kHz to 9, 10.7, or even 13 MHz). The next thing to do is build an amplifier that is tuned to 102,000 Hz, and that amplifier is called an *intermediate-frequency* amplifier (*i-f* for short).

At this point the sideband signal is considerably stronger than it was when it first came down the lead-in wire to your receiver terminals, and the i-f amplifier does not need such a terrific amount of gain. Now it is safe to turn on a carrier oscillator at a frequency of 100,000 Hz. With proper circuit design and good shielding in

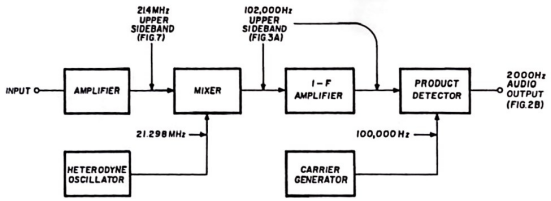


Fig. 8. A block diagram of the basic ssb receiver as set up to receive a signal at 21.4 MHz. Additional "niceties," such as variable tuning controls, automatic gain control (to keep the audio from being too loud), and audio amplifier circuits are not shown in the interest of clarity. For the waveforms and relationships involved at the various points in the circuit, refer to the figures indicated.

the receiver, this carrier will not bother the amplifier much, and will mix with the ssb signal to produce the 2000-Hz tone that you wanted all along.

An important thing to remember during all of this heterodyning process is that in order to preserve the original relationship between the sidebands and the carrier, you must keep the carrier in the right place.

Any time that any carrier is placed on the same side of the sideband as the higher audio tones, the product will come out upside down. See **Fig. 4.** Because of internal design problems (or simply because the builder wanted to do it that way) some receivers allow this to happen. In some units the audio can be turned over again by means of a switch that automaticlly moves the local carrier to the other side of the sideband, in other receivers, you must flip a switch yourself to accomplish the same thing.

There are a lot of tricks that can be put into receivers that will make life easier than with the overly simplified example that I have used here. F'r instance, a good filter is needed to be sure that you listen to only one sideband signal at a time (well . . . almost just one, the frequencies *are* crowded). The filters used can be identical to the ones used in the sideband generator that I told you about last time. In fact, most transceivers (transmitter and receiver in the same box) have some pretty nifty circuits in them so that they use the exact same filter for both creating the sideband and for receiving it. Many other parts of the circuitry can be shared equally between the transmitter and receiver, too, but you had better practice reading road maps before trying to follow the signal path through a present-day transceiver.

Another nice thing to have is called agc, for automatic gain control. This is a specialized rectifier circuit that senses how strong the signal is when it comes in, and by means of some tricky amplification, turns the volume control down (electronically) so that Mr. Loud-Guy on the next block doesn't take your head off when you are listening for a weak one.

As a closing note, I hope you are not fed up with Heterodyne, because he still figures in the plot in a couple of places. I haven't told you what he does in transmitters yet, but I will!

HRH

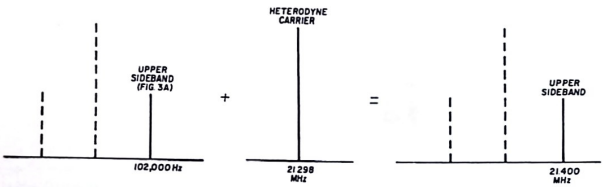


Fig. 7. Many ssb transmitters first generate the sideband signal at a lower frequency and then "translate" it to a desired ham band by one or more steps of mixing. Here you can see the addition process that will heterodyne the 102,000 hertz sideband signal up to the amateur 21-MHz band. The proper carrier-to-sideband relationship must be maintained, as explained in Fig. 4.

SINGLE SIDEBAND

Part 3

First process the speech, then translate it to a useful frequency

BY THOMAS McMULLEN, W1SL

In the previous two issues of *Ham Radio Horizons* I talked about single-sideband in general, covering the reasons for the improvement in communications ability, and about receiving ssb. Much of the information covered is still applicable to this part of the ssb picture — transmitting. The basic process of generating the sideband signal has been explained, which makes this "transmitting" portion of the discussion a bit easier. All that remains is to delve just a bit more into the generation process, and then apply the principle to developing a useful signal for some of the popular amateur bands.

Audio processing

Throughout most of this discussion I have talked about a single audio tone instead of a "band" of tones or frequencies, just to make the steps a bit easier to follow. Where reference was made to voice frequencies, the example used was limited to frequencies between 100 and 5000 hertz. I am sure that you realize that many voices cover more than that range, depending upon the gender and individual characteristics (**Fig. 1**). Actually, the range of voice frequencies used in ssb communication is made even more narrow — 300 to 3000 hertz in some instances. This practice did not apply only to the development of ssb, though. As far back as the middle 1930s the more popular ham bands were becoming crowded enough that many authorities recommended that the speech-amplifiers in a-m (amplitude modulated) transmitters be modified to limit the range of frequencies that would be amplified especially the higher tones. Not too many amateurs were enthused about giving up their "wide-range" sound on the air, but there was a small group that did follow the suggestion. Part of the great space-saving ability of ssb is that one sideband and the carrier has been eliminated, as we have seen. Almost as important is the restricted range of frequencies that the audio amplifiers and filters will allow to pass (**Fig. 1**). Considerable experience was required before a majority of amateurs were convinced that it really was possible to transmit reasonable sounding audio — good enough for communications purposes — by using only part of the voice frequencies. This not only had the benefit of decreasing the spectrum taken up by each signal, but the additional filtering involved in the receivers allowed the amateur to "hear better" as well. Transmitters could "punch through" when the conditions got rough, and the receivers could "dig down deep" in the layers of signals that sometimes appeared when a rare station made its presence known.

A second type of speech processing is very much talked about today, and it has both good and bad points. This system is one of trying to fill in the valleys between voice peaks, thereby making the transmitter more efficient. The human voice is a very complex thing, and there still is much research being done to analyze the purpose and effects of each part of the spoken sound. In addition to the wide range of tones found in the voice, there are also great variations in the strength, or amplitude, of those tones. An example of this is shown in **Fig. 2**. The greatest amplitude represented in the drawing is called the "peak." It is that part of the voice that drives the transmitter to its greatest output, so you can see that if the "peak" voltage is there for only a short period of time, then the transmitter is sending out its maximum power for a correspondingly short time. If there was some way to increase either the length of time of the peak, or to build up the portions that were not as "loud," it should cause the transmitter to produce its greatest power for a longer time.

The type of speech processing that does this little trick can perform its deed either by limiting the amplitude of the strongest parts, while allowing the weaker ones to go untouched, or it can use a complex circuit that detects how strong the signal is, and by electronically changing the gain of a stage, force the output to stay at or below a desired level. In other words, the stronger you talk, the more

off it turns the amplifier!

Either the limiting or the gain-changing method must be accompanied by numerous other circuits that do such things as keep the voice from becoming badly distorted, keep the amplifiers from creating new frequencies outside the voice range, and other housekeeping duties. There are several ways of getting to the same goal, and, since the confusion factor is high enough with just the basics of ssb, I'll not go into all that in this series.

Some of the benefits of speech processing for ssb are; **a**) you get more overall efficiency from a transmitter because it is kept working hard longer, **b**) it fills the frequency (channel) you are using with more signal, thus making it easier to receive at the other end, and **c**) it can build a weaker voice up to a real "loudmouth" level if needed. Most of the disadvantages tend to show up when a speech processing system is misadjusted or improperly used. If the overall gain is set too high, background noises tend to be almost as loud as you are — believe it or not, most people do not like to hear the dog barking next door, your kids playing upstairs, and the Saturday Night Movie from the TV set, all while you are trying to say something. Furthermore, if the amount of limiting or compression is set too great (not enough difference between the peaks and valleys) the voice loses its character and people will wonder if you are in great pain. Certainly either condition is not of great value to communication.

Another fault with the use of many processors lies in the mistaken idea that there is no limit to the amount of improvement in output power that can be obtained by simply turning up the gain knob or by talking closer or louder. The limitation comes in the transmitter elements themselves. Many tubes and transistors are working close to their rated values in Amateur equipment, and it does not take much of an increase in input from the speech end of things to make them reach their limit. Beyond that limit, any further "push" from the microphone will simply cause the transmitter to "saturate," which means that it has "had it right up to here," and cannot work any harder. Under these conditions, you are most likely doing more harm than good, because the people who want to carry on a conversation on an adjacent frequency are being "splattered on."

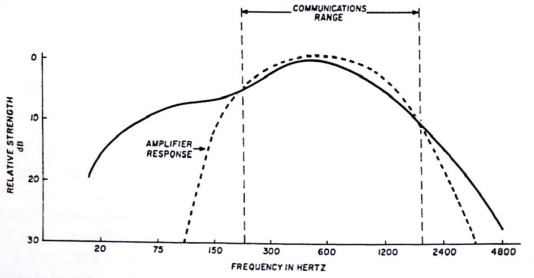


Fig. 1. The power involved in voice frequencies shows a response peak between 400 and 1000 hertz. This plot is for an average male voice when speaking at normal loudness. By selecting the proper portion of the curve, none of the essential tones necessary for communicating are lost. The dotted line shows an idealized response curve for an audio amplifier that would let the important parts of speech through. If the curve were shifted lower, the voice would sound boomy; emphasizing the higher parts would cause the voice to sound tinny and lack "punch."

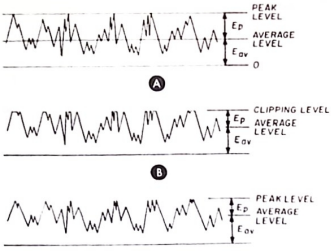


Fig. 2. Speech processors can also be designed to reshape the maximum strength of the modulating tones or voice. The variations in average voice peaks can be seen in **A**. A clipper can be designed into the circuit, and will remove the upper part of the highest peaks, **B**. A volume compressor or gain-reducing circuit will keep the original form of the peaks, but prevent them from rising as high, shown in **C**. The important thing here is that the *average* level is increased, thereby allowing better efficiency in the transmitter and improved signal readability.

Modulator or mixer

In earlier portions of this series, I used the terms "balanced modulator," "balanced mixer," and "mixer," from time to time. In many ways they are alike — practically interchangable. It's just that if you are using a given circuit as a part of a transmitter that produces a sideband signal from voice, then you call it a modulator. If you happen to use the same one for the purpose of translating a low-frequency to a higher one, or vice-versa, then it is more properly called a mixer. The balanced part stems from the application of the voltages in such a manner that the whole circuit is working, rather than having one part of the circuit working against ground (**Fig. 3**).

In part 1, I explained how a sideband was generated, and in part 2 I showed how it could be translated to a particular Amateur frequency (and then "detranslated" so you could hear it). Now I'll refresh your memory and at the same time use as a practical example some frequencies that might

be found in a piece of modern ssb gear.

In **Fig. 4**, you can see the familiar balanced modulator that has been talked about before, along with a speech amplifier and a carrier generator. Since this is not a construction article, I have not shown all of the components needed to build a circuit like this. However, there have been many very similar circuits published in Amateur literature, so if you would like to explore further, you can do so. (See References for additional reading suggestions). The carrier used here is 9 MHz, and the carrier-generator oscillator is crystal controlled. Either upper or lower sideband can be obtained by simply switching the crystal that is in use.

Following the balanced modulator you will notice a filter. This is a crystal filter that has the response curve necessary to select the right portion of the sideband and reject the unwanted parts, along with the unwanted sideband. (Refer to **Fig. 5** in the March issue). The filter stage is followed by an amplifier, necessary because the filter has an appreciable loss (you get less out than you put in), which is, in turn, followed by a mixer.

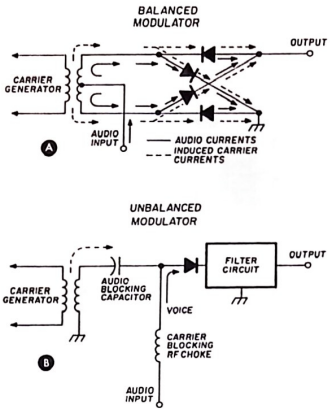


Fig. 3. The balanced modulator **A**, is used in many ssb-generating circuits because of its greater efficiency and because the carrier more effectively cancels itself after performing the basic function of turning the diodes on and off at a rapid rate. This is in contrast to the unbalanced modulator (or mixer) at **B**, which requires good filters at the output to remove leftover carrier energy.

This mixer is a "translating" stage, or (here *he* comes again!) it *heterodynes* the 9-MHz sideband signal to an Amateur band. Here I have placed more crystals and a vfo in the circuit. Thus you can select an output frequency in the 3.8-, 7-, 14-, 21-, or 28-MHz band. Nothing hard about that — it is nearly the same as I told you about last month in the receiver portion of the series. But, with one of these switch positions I am pulling a sneaky on you. When you switch the vfo to obtain an output on the 3.8-MHz band, the voice comes out upside down! (Remember **Fig. 4** in the April issue?) There's an easy cure for that, however — you simply connect this set of crystals and the 9-MHz carrier generator crystals to the same switch, and wire them so that it changes the crystal at the same time you change bands. How about that! Incidently, the voice starts out upside-down, right from the modulator and filter. It has to because of the frequency translation that takes place in the second mixer for the bands 40 through 10 meters. The mixer stage should be followed by several

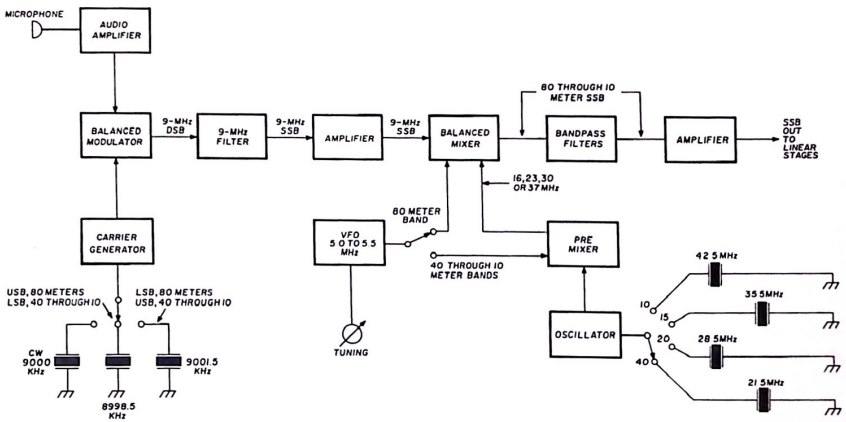


Fig. 4. A simplified block diagram of an ssb transmitter that is typical of many units in use today. The choice of frequencies to use for generating the basic ssb signal is determined somewhat by the availability of good filter components. Fortunately there are several good crystal filters available in the hf range between 3 and 21 MHz. However, great care must be used in selecting all of the frequencies involved because unwanted mixing products are often difficult to eliminate. They could cause trouble by being transmitted along with the correct product, or could block the receiver with a very strong signal.

amplifiers, of course, because the power level at this point is very low — only a few tenths of a watt. Several stages can be used, one after another, until the power is built up to whatever level is needed — hundreds or thousands of watts.

The "third method"

I have already talked about two common types of ssb generated circuits, the filter type and the phasing type. There is another way of obtaining a sideband signal; one quite popular in Europe and England. Generally, it is referred to as the "third method." It may eventually gain in popularity over a larger part of the world because it makes use of some digital circuitry, which is the "in" thing these days.

A block diagram of a system using the "third method" is shown in **Fig. 5**. The basic generation can be accomplished in six integrated circuits. Other circuitry, not shown, is required to provide the clock input, and of course there must be an audio amplifier stage and a vfo to complete the picture. In one example of this system, reported in the Radio Society of Great Britain publication *Radio Communication*, October, 1974, the designer (A. de Muijnkc of Holland) used 7400 Hz as the clock input and a vfo frequency of 14 MHz, to provide ssb output in the 3.5- to 4-MHz band. (See References for further reading).

It is basically a phasing type of generator, with the phase changes taking place in the frequency-divider ICs. For those of you who are not familiar with the workings of digital circuitry, let me point out that the output of a divider, such as the 7473 used here, consists of a pulse from what is termed the "Q" output, and another from what is called the "not-Q," represented by an overscored Q ($\overline{Q}$). The $\overline{Q}$ output is off

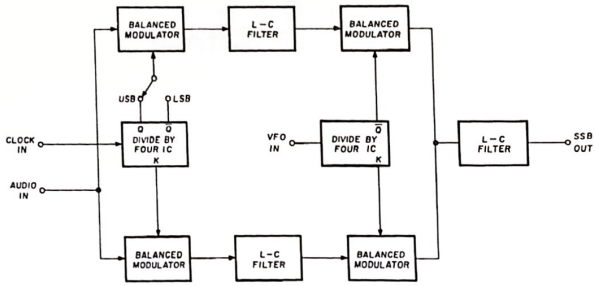


Fig. 5. A block diagram of a "third-method" of developing ssb. Although it is a variation of the phasing system, it makes use of modern components and digital techniques to an extent. Because of the upper frequency limit of most divider ICs, the system works to approximately 8 MHz. Improved integrated circuits could extend this limit. The "clock" mentioned in the text and shown here has nothing to do with timekeeping in the normal sense, but rather designates the function of turning a portion of the circuit on and off at a periodic rate.

whenever the Q is on, and vice versa, thus one IC can give you two outputs, which are 180 degrees out of phase with each other, and an output from the K section that is 90° out of phase with both the Q and the $\overline{Q}$ pulses.

An advantage to this method of ssb generation is that the filters needed are relatively simple and inexpensive, consisting mainly of inductance and capacitance in combination. Another plus is that the system can directly produce a variable-frequency output, without the addition of an external mixer that accepts the ssb and the vfo input. A disadvantage, at the moment, is that the frequency-divider ICs most commonly available will operate only to 30 or 40 MHz. Since the vfo input must be at four times the expected output frequency, this puts a limit on the number of bands that can be covered with present ICs. There are some dividers available that work well into the uhf range, but the expense is prohibitive.

Conclusion

This series of ssb exploration articles has been intended to help the beginner to understand some of what goes on inside the many boxes that send and receive that mode. There are many variations in the approach to building an ssb transmitter, receiver, or transceiver. However, they must all follow one of the three methods I have talked about, at least until someone finds a "fourth method." A reference section follows, containing some recommended reading for those who would like to delve deeper into the principles, circuitry, and perhaps the ways in which you can build your own.

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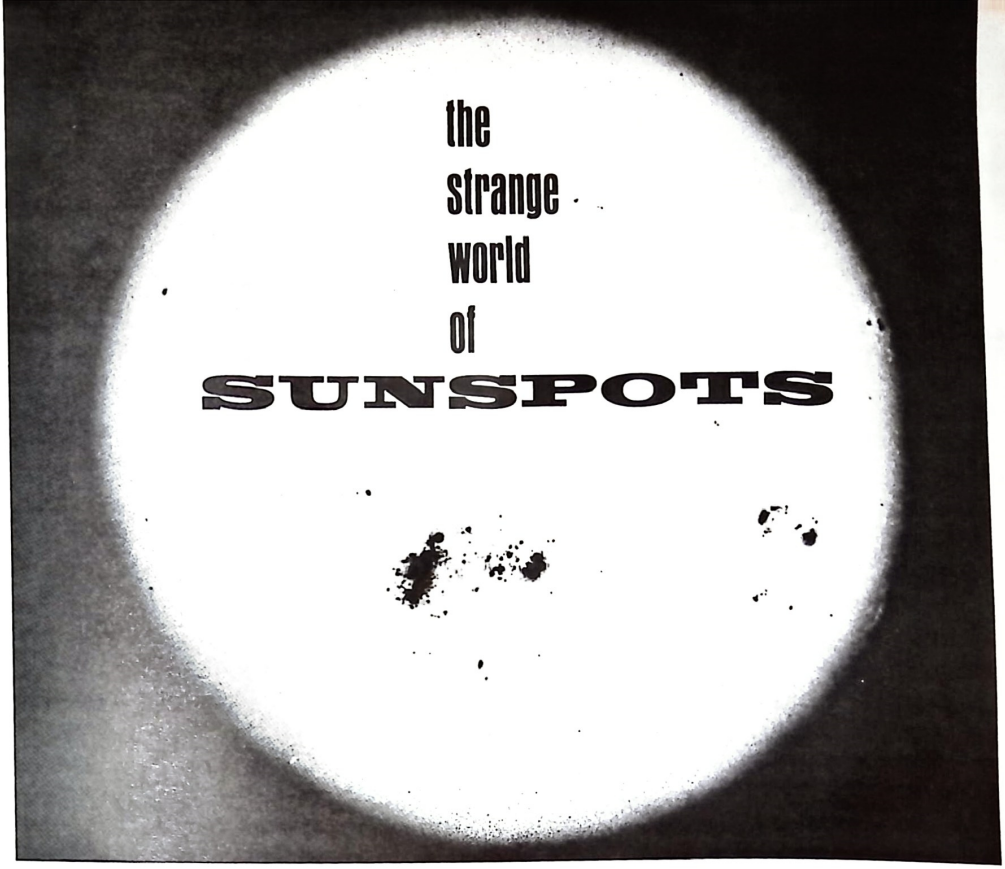


BY WILLIAM I. ORR, W6SAI

DX conditions during 1977-1978 and thereafter

"You should have heard 20 meters last night! The Russian and Indian stations were louder than the locals! UK9LAB was 20 dB over S9. Conditions were just fantastic!"

"Gosh, 10 and 15 meters have been dead as a doornail since last summer when I worked some short-skip signals. I always thought those were DX bands. Why did I hear all those short-skip stations?

"Did you hear that some fellows have made WAC on 160 meters? I always thought that was a short distance band!"

"Yesterday morning I heard European signals coming through on 80-meter sideband, and there were also some JA signals in there!"

DX is where you find it. Somedays the bands are good and somedays they are bad. Most Novices and beginners are aware of the irregularities of the amateur bands, and have heard remarks about the *sunspot cycle* and rumors that the bands will get better or worse during the next few years. But the sunspot cycle and its effect upon radio propagation is not generally understood, even though its influence upon radio conditions will be profound during the coming years. This is a short summary of what is going on in this regard, and what probably will happen to hf radio conditions during the next few years.

The Ionosphere

Long distance radio communication is possible because radio waves are reflected to earth from the *ionosphere*. This is a region high above the earth's surface where the rarefied air is sufficiently ionized by ultraviolet light from the sun to reflect or absorb radio waves. The ionosphere is defined as that region lying about 30 to 250 miles (50 to 400 km) above

the surface of the earth. It is the ionosphere, acting like a gigantic radio mirror that is responsible for good or bad radio conditions.

The reflectivity (or ionization) of the ionosphere is a function of radiation from the sun (**Fig. 1**), and the greater the reflectivity, the better the radio conditions. As ionization diminishes, radio conditions become poorer.

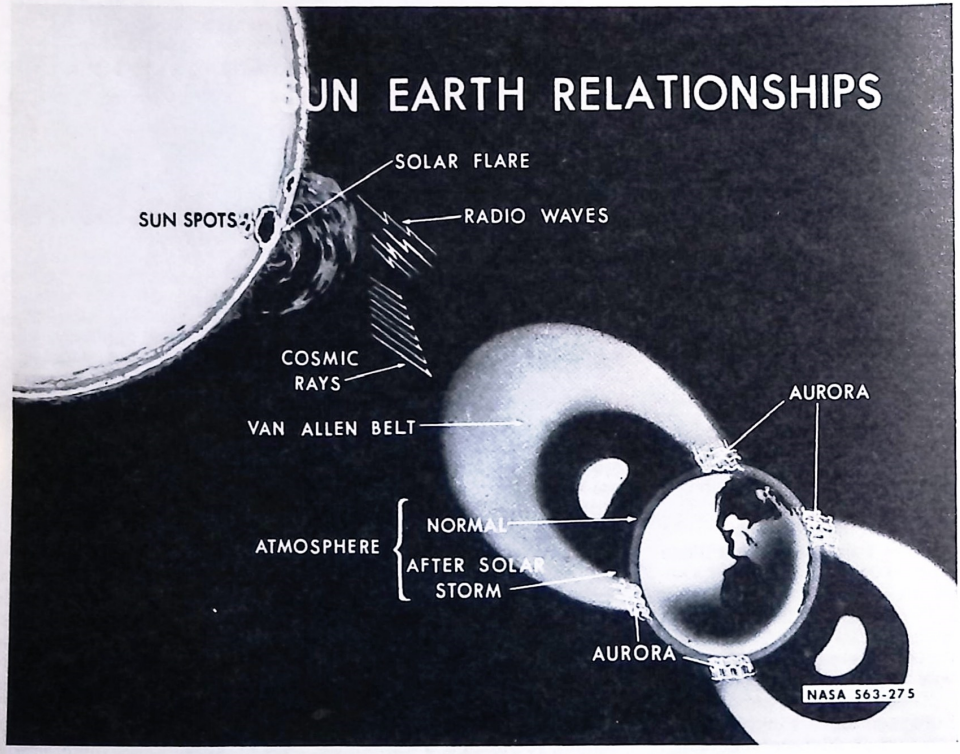
The amount of radiation falling upon the ionosphere varies hourly, daily, seasonally and geographically, depending upon the relationship between the sun and the earth. In addition, year-to-year changes, over an approximate 11-year cycle, cause vast changes in the ionosphere's ability to reflect radio waves. These changes, which result from the variation in the number of sunspots on the face of the sun, over 90,000,000 miles away, are the key to radio conditions on earth!

Cycles in Ionospheric Activity

The first recorded observations of sunspots were made by Chinese astronomers more than 2000 years ago. For centuries, the dark spots on the sun were thought to be slow, high-flying animals or perhaps clouds. Galileo, considered by many to be the inventor of the modern telescope, observed the blemishes on the sun and, in 1611, noted that the spots were on, or close to, the sun. He also observed that they were carried around the sun by its rotation, which seemed to take a period of about a month.

There the matter rested until 1908, when astronomers carefully photographed the sun and determined that the sunspots actually were whirling storms on the surface of the sun. These storms are accompanied by magnetic disturbances that generate eruptions of gaseous material, breaking through the sun's surface to create whirling "spots" of electrified material

Fig. 1. The sun-earth relationships. Radiation from the sun covers the entire electromagnetic spectrum. Of great interest to users of the communication spectrum are radio waves and ultraviolet radiation. Solar flares on the sun create "radio blackouts" and sunspots seem to govern high frequency radio conditions. Effect of sun's radiation on earth, together with earth's magnetic field, creates the Van Allen belt of radiation and the aurora. Complex interplay of radiant energy received from the sun and its effect upon mankind are not fully understood (*drawing courtesy NASA*).



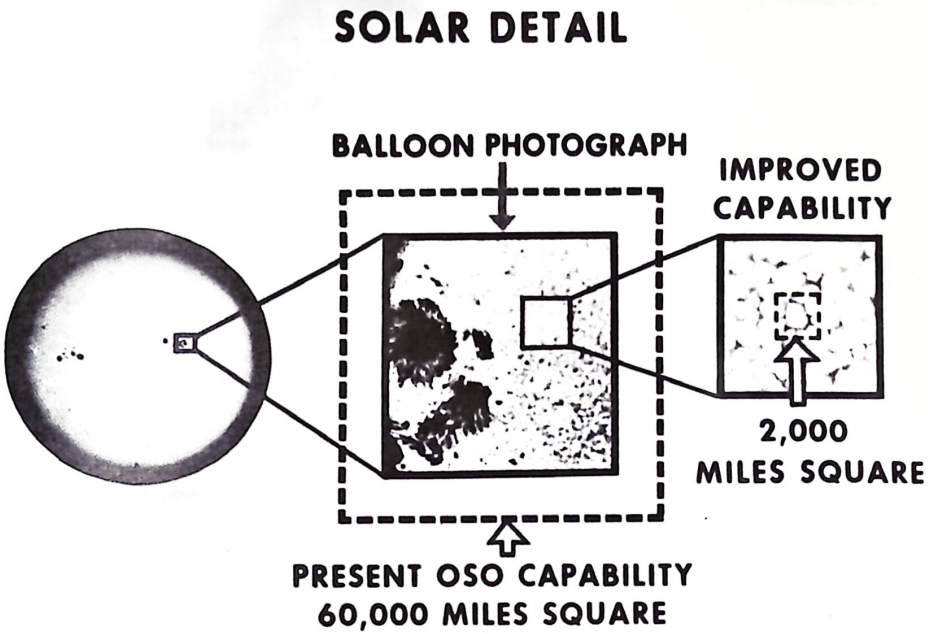


Fig. 2. Orbiting Solar Observatory (OSO) studies sunspots. A photographic close-up of a sunspot (center) shows the whirling storm on the sun's surface. Future capability of OSO will show small details of sun's surface, right. (*Drawing courtesy NASA*).

hundred of thousands of miles in diameter (**Fig. 2**).

About the middle of the 18th century, astronomers began to keep records of the sunspot count and by 1843, it was realized that the count varied, with sunspots appearing and disappearing in a periodic fashion, varying from a minimum to a maximum and back again in about 10 to 11 years. A plot of the sunspot cycle covering 1832-1932 is illustrated in **Fig. 3**.

The plot reveals that the sunspot maxima and minima are irregular, the length of the cycle varying from under 7 years to over 17 years, the minimum sunspot count varying from zero to nearly 12, and the maximum count varying from 45 to over 200. All of this was of academic interest only until the early nineteen thirties, when it was noted that there was a direct relationship between the smoothed sunspot number and the intensity of ultraviolet radiation from the sun. This discovery was of paramount importance because it directly associated the sunspot count with long-distance radio propagation.

The Sunspots and Radio Communication

It is now known that the sunspot cycle is a reliable index of the ionosphere's capability to reflect high frequency radio waves. In brief, when the smoothed sunspot count is high, a wide range of frequencies between about 3 MHz and 40 MHz is reflected over great distances. As the sunspot count declines, the ability of the ionosphere to reflect radio waves is diminished, and the upper limit of the frequency range reflected decreases from about 40 MHz to 20 MHz, or less.

During the peaks of the last two great cycles, frequencies higher than 50 MHz were reflected great distances (**Fig. 4**). During the spring months of 1958, for example, international DX contacts on the Amateur 6-meter band were commonplace and the 10-meter band was open for DX work nearly 24 hours a day!

As every alert Novice or beginner knows, radio conditions today are not nearly as impressive; long-distance DX is notably absent from the 6-and 10-meter bands, and shows up only occasionally on the 15-meter band. On the other hand, the DX-ability of the 160- and 80-meter bands seems considerably enhanced compared to more normal periods of radio activity.

What, then, is going on? Are radio conditions going to improve or deteriorate over the next few years? What can we look forward to in terms of radio communication between now and 1980?

The answer can be predicted, and long-range forecasts of radio communication in the years ahead can be made; but, since there is at present no satisfactory theory that fully explains the cause of sunspots, or the sunspot cycle, an *exact* prediction of their future behavior is out of the question. However, from the cyclic nature of the sunspot cycle certain assumptions can be made, and various empirical methods have been developed for determining future solar activity.

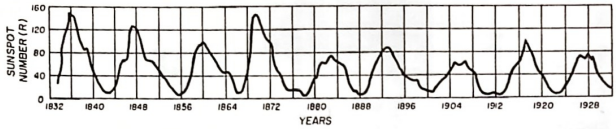


Fig. 3. Plot of sunspot cycle (smoothed) for the period 1832-1932. The sunspot cycle was viewed as an academic curiosity until about 1932 when it was observed to correlate closely with high frequency ionospheric radio propagation. Since that discovery, the sunspot cycle has been found to have direct and emphatic effect upon radio conditions, and particularly on the maximum usable frequency for any long distance radio circuit (*chart courtesy of Bell Telephone Laboratories*).

The Solar Cycle: Where We Stand

The present portion of the solar cycle is illustrated in **Fig. 5**. It can be seen that this cycle started about the summer of 1964 and reached a maximum number of about 110 sunspots in mid-1968. Since then, the sunspot count has been declining at a slow rate, with the next sunspot low predicted to arrive during the spring of 1977. Predictions for the next sunspot cycle, to start in early 1977, indicate a rather low, broad peak reaching a maximum count of about 55 to 75 in late 1982. The following minimum will then be reached about 1988. An extended prediction (guess) indicates that sunspot numbers in excess of 100 will not be observed again until approximately the year 2015! Thus, the next 40 years may be characterized by relatively low sunspot activity compared to the activity of the last 40 years.

The implications of low sunspot activity with respect to ionospheric propagation of radio waves is obvious. Long-distance propagation will be more infrequent than in the past years of high sunspot activity, and will occur for shorter periods of time at reduced signal levels. The lower frequencies (those below 8 MHz) however, may show improvement even though the higher frequencies may provide marginal performance.

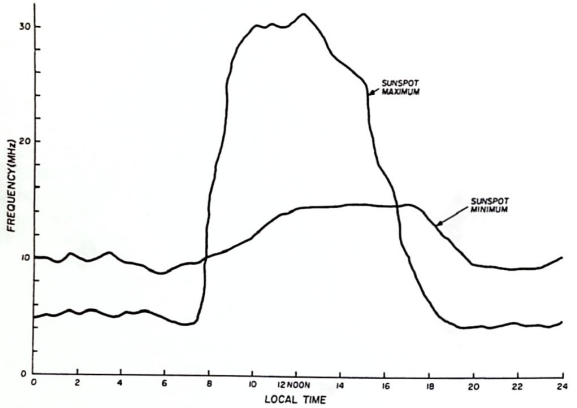


Fig. 4. The maximum usable frequency for a given transmission path is highest during maximum sunspot activity. Ionospheric losses are at a minimum during daylight hours and increase rapidly for lower frequencies. During a sunspot minimum, the maximum usable frequency is much lower, and ionospheric losses are higher. The lowest usable high frequency depends primarily upon static and atmospheric noise at the receiving end of the circuit. During the sunspot maximum this typical circuit will support communication as high as 30 MHz during daylight hours, whereas at the sunspot minimum the maximum daylight frequency that can be used is only about 15 MHz.

The Immediate Future

The winter and spring of 1976-1977 mark the bottom of the old sunspot cycle and the start of the new one. If it progresses as is predicted, the new cycle will resemble **Fig. 6**. The years of 1977 and 1978 are years of transition. During these years, as the new cycle starts its course, the sunspot count will be very low, but rising. The usable high frequency spectrum has shrunk to about half that available during periods of high solar activity. Emphasis will remain with the lower frequency amateur bands (160 through 20 meters). The low bands — 160 and 80 meters — will exhibit DX openings to many areas of the world during the hours of darkness in the late fall, winter and early spring months. Twenty meters will continue to be the best overall DX band with openings all over the world from just past sunrise to shortly before sunset, and late in the evening during the late spring and summer months.

The 15-meter band should show improvement in DX as the sunspot count slowly rises. Good north-south contacts were logged during 1976, and these should improve both in

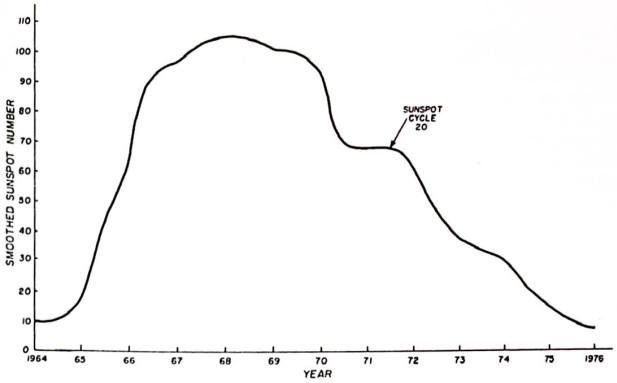


Fig. 5. The just-completed sunspot cycle (number 20 in the numbering system) began in 1964 and reached a peak of about 110 in mid-1968. A "plateau" showed up during 1970-72 when the count remained between 70 and 60. Since then, the count has declined smoothly and rapidly, reaching approximately six near the end of 1976 (*data courtesy George Jacobs, W3ASK*).

duration and signal strength during 1977. Fifteen meters, however, will remain a daylight DX band during the next year. Very few DX openings are to be expected on 10 meters, but occasional north-south contacts should start to show up in the fall of 1977.

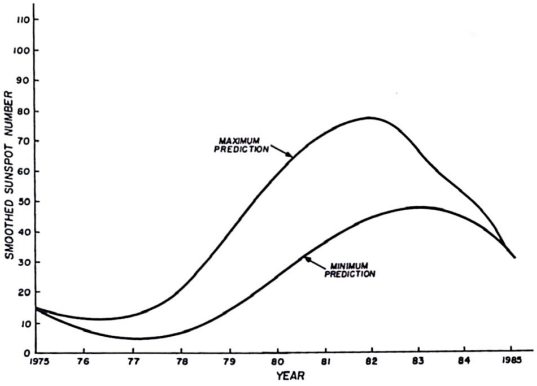
As the sunspot count slowly rises during 1978-79, conditions on 10 and 15 meters should improve, and by 1979 the 15-meter band should be a close rival to 20 meters for DX work. By 1980-81, the 10-meter band should be back in business for DX as the sunspot count slowly and inexorably rises.

The time period from 1980 through 1985 should be the "golden years" of Amateur high frequency DX communication, because during this interval the number of sunspots will reach a maximum value.

Interestingly enough, the predicted low cycle should be excellent as far as Amateur Radio goes, particularly with respect to the 20-, 15-, and 10-meter bands. A too-high cycle can provide DX work on the 6 meter band; as the cycle advances, so does ionospheric absorption, limiting the DX-ability of the lower frequency amateur bands.

In summary, then, DX conditions will remain virtually as-is for the next year, then gradually perk up during 1978. The 15-meter band will be the first one to note the improvement, followed a year or so later by the 10-meter band. At the other end of the spectrum, the excellent DX characteristics noted on the 160- and 80-meter bands will gradually decline.

Fig. 6. Predictions of things to come. Two views of sunspot cycle 21. The maximum smoothed sunspot number is predicted to fall between 45 and 85 sometime between 1981 and 1984. Other predictions abound, one of them predicting the highest sunspot cycle ever recorded! As the years go by, scientists will more fully understand the mysterious, boiling spots on the sun that affect radio communication, the weather and perhaps even human life on the planet earth (*data courtesy George Jacobs, W3ASK*).



Other Factors Influence DX

The sunspot cycle is not the only natural phenomena that influences the high frequency bands. Abnormal ionospheric variations exist, and among the most common of these are the *ionospheric storm* and the *sudden ionospheric disturbance* (SID). The storm can develop gradually or it may start in a few hours. It may continue for a day or so, or last as long as a week. The SID usually commences very suddenly and lasts from 30 minutes to an hour or two. Both types of ionospheric disturbance are similar in that they cause a drastic increase in ionospheric absorption with an accompanying "radio fade-out" that will make the newcomer think his receiver has gone dead!

These disturbances are more noticeable on the higher bands, but severe storms may even disrupt communication on the 80- and 160-meter amateur bands. The SIDs occur during the peak of the sunspot cycle and are quite rare during the low portion of the cycle.

Sporadic-E Transmission

The irregular formation of "clouds" of ionization in the ionosphere during the summer months brings about an unusual form of long-distance radio communication called *sporadic-E* transmission. This phenomenon bears little resemblance to normal propagation. It is highly unpredictable and is responsible for most of the 21 and 28 MHz long-distance contacts during the warmer months. Sporadic-E will support communication up to 1400 miles (2200km) on frequencies considerably higher than those being reflected by the normal ionophere. It is suspected that sporadic-E reflection is the result of ultraviolet radiation from the sun which, in combination with high speed winds blowing in different directions at a height of about 40 miles (65km), cause redistribution of electrified particles in the atmosphere into dense patches of ionization. In this manner, the ionized regions required to reflect high frequency radio waves back to earth are temporarily created without any total increase in overall ionization. Sporadic-E transmission usually results in very strong signals with rapid fading and quick "drop out" as the cloud moves across the face of the earth. This type of propagation is more common in the latitudes near the equator than in the more northerly latitudes.

There's More to the Story

This article has barely touched the surface of radio propagation, which is a fascinating and interesting study. It is possible to predict short-term propagation conditions over various radio paths in advance using sunspot count and other data. In a future issue of this magazine, vhf propagation will be discussed for the benefit of the Novice and the newcomer.

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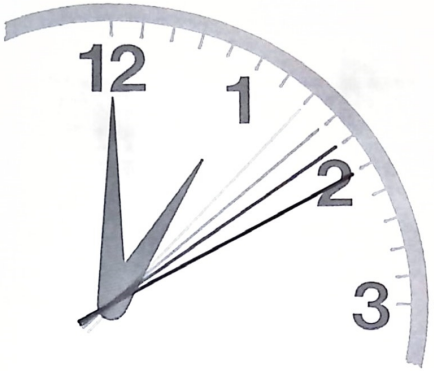


Time and Time Again

"When the tone returns, the exact time will be . . ."

BY JAMES H. GRAY, W2EUQ

"My watch has stopped again! What time is it, anyway?" Sound familiar? This scene is repeated daily, with variations, everywhere on earth by thousands of people in all walks of life. Like it or not, we live by the clock, and the world's work depends upon knowing what time it is.

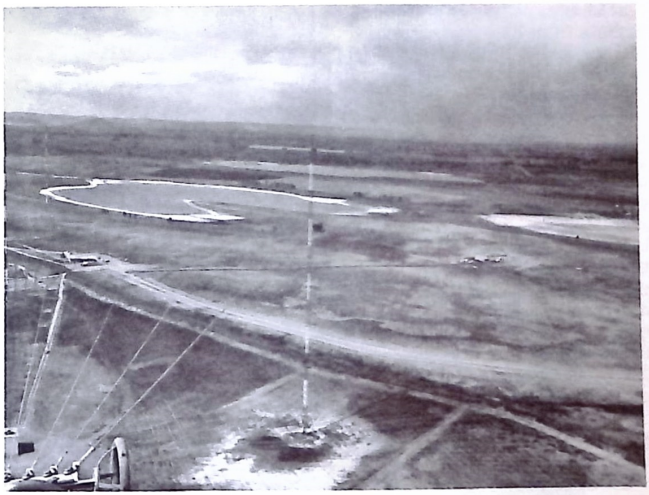
Astronomers and observatories, airlines and marine shipping companies, electric power and telephone companies, radio and TV broadcasting stations, research laboratories, scientific and industrial organizations, navigators, and even Radio Amateurs and shortwave listeners have a need to know the correct time to successfully carry on their activities. Man regulates his life by the clock and apparently has always done so, even in prehistoric times, if the pyramids, Stonehenge, and Mayan sundials and calendars are meaningful.

Sundials gave way to water clocks which, in turn, yielded to weight-operated clocks, and finally to spring-driven timepieces. These familiar and ordinary watches and clocks, in turn, were replaced by electrically or electronically regulated devices which depend upon mechanical tuning forks or piezo electric crystal oscillators to provide increasingly accurate time information. For laboratory and similar standards, even these aren't accurate enough, and the major standards are now controlled by "atomic clocks," in which atoms of the elements cesium or rubidium provide the frequency — hence, time — control.

In the United States, the National Bureau of Standards operates radio stations WWV, WWVH, WWVB, and WWVL which provide standard signals together with many other useful services; and in Canada, the National Research Council operates radio station CHU, which provides the time service.

Let's take a look at these two major facilities in more detail, with an eye toward the type of

A view of both WWVB/WWVL and WWV (right) from the top of one of the antenna-support towers. The steering-wheel-like objects at the lower left are anti-static or anti-corona devices (*photo courtesy US Department of Commerce*).



information that is provided and by what means.

WWV and WWVH

For more than 50 years, the National Bureau of Standards, (NBS), under the United States Department of Commerce, has provided internationally-recognized time and frequency standards for worldwide users of this service.

Since the inception of the broadcast services from radio station WWV in 1923, NBS has continually improved and expanded its time and frequency dissemination services to meet the needs of a growing community of users in the United States and elsewhere. NBS has made, and continues to make, major contributions to the nation's space and defense programs, to worldwide transportation and communications, and to a multitude of industrial operations.

In addition, NBS provides a convenient, highly accurate time service to thousands of users throughout the world. Its services are available from station WWV and WWVB in Fort Collins, Colorado, and from WWVH in Kauai, Hawaii. Beyond this, a new calibration method using network television is also available.

NBS broadcasts continuous signals from its high-frequency radio stations WWV and WWVH on 2.5, 5, 10, and 15 MHz. These widely-spaced frequencies practically insure that users anywhere in the United States can receive at least one of them at any time of the day or night to receive needed time and frequency information. Except during times of severe magnetic disturbances, which tend to make all reception of radio transmission impossible, listeners will find that the frequencies above 10 MHz provide the best daytime reception, while frequencies below 10 MHz provide the best night-time reception.

Services provided by these stations include: time announcements, standard time intervals, standard frequencies, geophysical alerts, marine storm warnings, time corrections, and a BCD time code. The format of the broadcasts, and the hourly schedule is shown in **Fig. 1**.

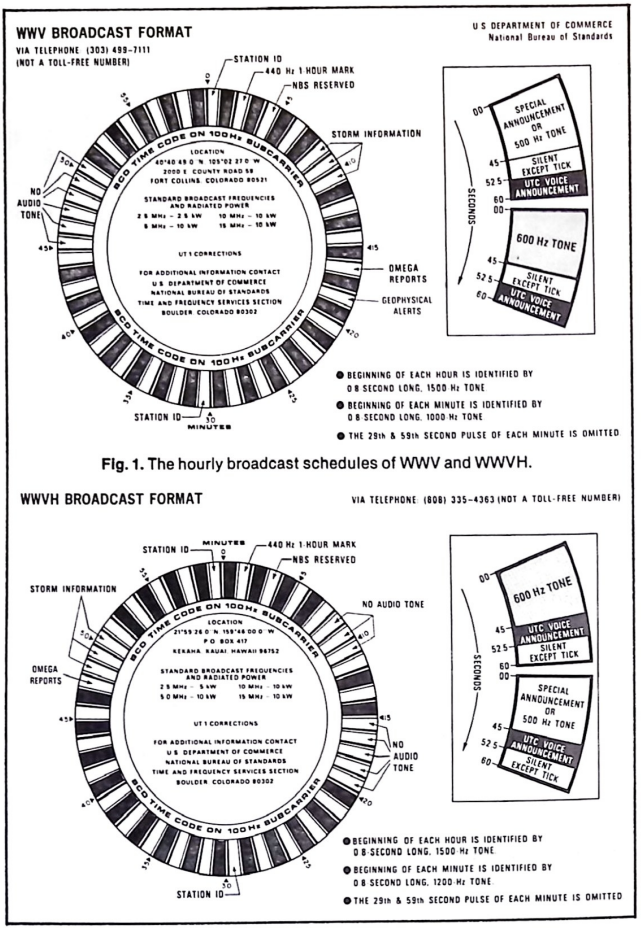

WWV BROADCAST FORMAT
VIA TELEPHONE (303) 499-7111
(NOT A TOLL-FREE NUMBER)
U S DEPARTMENT OF COMMERCE
National Bureau of Standards
STATION ID
440 Hz 1 HOUR MARK
NBS RESERVED
STORM INFORMATION
NO AUDIO TONE
OMEGA REPORTS
GEOPHYSICAL ALERTS
BCD TIME CODE ON 100Hz SUBCARRIER
LOCATION
40°40 49 0 N 105°02 27 0 W
2000 E COUNTY ROAD 58
FORT COLLINS, COLORADO 80521
STANDARD BROADCAST FREQUENCIES AND RADIATED POWER
2 5 MHz – 2 5 kW
5 MHz – 10 kW
10 MHz – 10 kW
15 MHz – 10 kW
UT 1 CORRECTIONS
FOR ADDITIONAL INFORMATION CONTACT
U S DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
TIME AND FREQUENCY SERVICES SECTION
BOULDER COLORADO 80302
MINUTES
SECONDS
SPECIAL ANNOUNCEMENT OR 500 Hz TONE
SILENT EXCEPT TICK
UT1 VOICE ANNOUNCEMENT
600 Hz TONE
BEGINNING OF EACH HOUR IS IDENTIFIED BY 0 8 SECOND LONG, 1500 Hz TONE
BEGINNING OF EACH MINUTE IS IDENTIFIED BY 0 8 SECOND LONG, 1000 Hz TONE
THE 29th & 59th SECOND PULSE OF EACH MINUTE IS OMITTED
WWVH BROADCAST FORMAT
VIA TELEPHONE (808) 335-4363 (NOT A TOLL-FREE NUMBER)
LOCATION
21°59 26 0 N 159°46 00 0 W
P O BOX 417
KEKAHA, KAUAI, HAWAII 96752
BEGINNING OF EACH HOUR IS IDENTIFIED BY 0 8 SECOND LONG, 1500 Hz TONE
BEGINNING OF EACH MINUTE IS IDENTIFIED BY 0 8 SECOND LONG, 1200 Hz TONE
THE 29th & 59th SECOND PULSE OF EACH MINUTE IS OMITTED

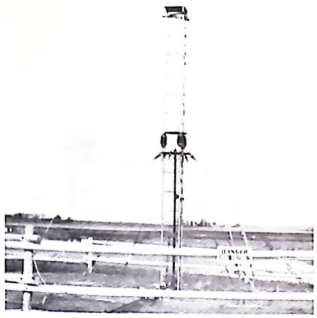
Fig. 1. The hourly broadcast schedules of WWV and WWVH.

Accuracy and stability

The NBS Primary Frequency Standard in Boulder, Colorado, controls all time and frequency broadcasts from its stations. The transmitted frequencies are accurate to *one part in 100 billion* at all times, and day-to-day deviations are normally less than *one part in 1000 billion*! Changes in the propagation medium, however, cause disturbances which result in fluctuations of the carrier frequency *as received* by the user. Such fluctuations can be much greater in magnitude than the uncertainty described above.

Time announcements

Voice announcements are made from WWV and WWVH once every minute and, to avoid confusion, a man's voice is used on WWV and a woman's



The 25-MHz dipole antenna near the WWV building. It is center fed by means of the 3-1/8 inch (8cm) transmission line you can see in the left foreground (*photo courtesy US Department of Commerce*).

voice on WWVH. The WWVH announcement comes first, at 15 seconds before the minute — while the WWV announcement occurs at 7½ seconds before the minute. The tone markers, however, are broadcast simultaneously from both stations but may not be *received* simultaneously because of propagation effects.

The time referred to in the announcements is *Coordinated Universal Time* (UTC), meaning that it is coordinated by the International Time Bureau (BIH) through international agreements, so that time signals broadcast by the many nations which provide a time and frequency service will be in close agreement.

The specific hour and minute mentioned in the broadcasts is actually the time in the time zone centered around Greenwich, England, and may be considered generally equivalent to the better-known *Greenwich Mean Time* (GMT). UTC differs from your local time by an integral number of hours, depending upon the time zone in which you live.

Many charts and maps are available to help you find the time anywhere in the world at a given GMT, and some clocks have appropriate dials to automatically give both GMT and the time at various locations around the world. For example, Eastern *Standard* Time is five hours *behind* GMT, while Eastern Daylight Time is only four hours behind GMT.

The UTC time announcements are expressed in the 24-hour clock system — *i.e.*, the hours are numbered beginning with 00 hours at midnight through 12 hours at noon to 23 hours, 59 minutes just before the next midnight. Among the many Amateur Radio operators, you will find that DXers and OSCAR users almost invariably use GMT (UTC), or "Zulu" time, in preference to local time. This is done so that stations at both ends of the circuit can be talking about the same time on particular days, and not different times on different days.

"Zulu" time may sound strange, but the logic becomes obvious when you understand the background. For convenience in specifying time, the military has divided the earth into 24 time zones, and has assigned to each time zone a letter of the alphabet (see **Fig. 2**). The "Z" time zone happens to coincide with Greenwich, England through which the zero meridian of longitude passes. Inasmuch as the letter *Z* can be confused with the letter *C* in voice transmissions, it has become customary to assign

The transmitters are located along corridors, with space behind the equipment racks for maintenance operations. These are in the WWV building (*photo courtesy US Department of Commerce*).

phonetics to each letter of the alphabet. Quite naturally, Z became the phonetic "Zulu" or "Zebra". Hence Zulu time means GMT.

Standard time intervals

The sounds most frequently heard on WWV and WWVH are the pulses that mark the seconds of each minute, except for the 29th or 59th second pulses which are omitted completely. The first pulse of every *hour* is an 800-millisecond pulse of 1500 Hz. The first pulse of every *minute* is an 800-millisecond pulse of

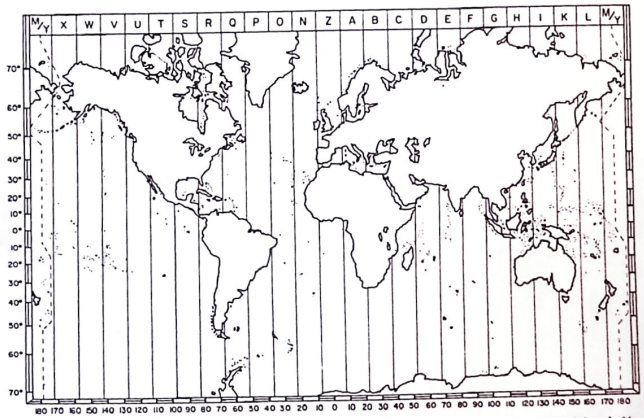


Fig. 2. World map showing the military time zones of the world identified by letter designators. Z (Zulu) time corresponds to GMT.

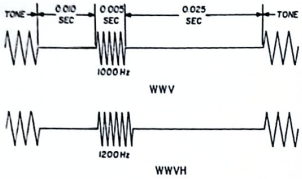


Fig. 3. Format of WWV and WWVH seconds pulses.

1000 Hz at WWV and 1200 Hz at WWVH. The remaining seconds pulse are brief audio bursts (5-millisecond pulses of 100 Hz at WWV and 1200 Hz at WWVH) that resemble the ticking of a clock. All pulses commence at the *beginning* of each second and are transmitted by means of double-sideband, amplitude modulation. Each seconds' pulse is preceded by 10 milliseconds of silence and followed by 25 milliseconds of silence to avoid interference which might make it difficult or impossible to pick out the seconds pulses. **Fig. 3** illustrates this total 40-millisecond protected zone surrounding each seconds pulse.

Standard audio frequencies

In alternate minutes during most of each hour, 500- or 600-Hz audio tones are broadcast. A 440-Hz tone, the musical note A above middle C, is broadcast once each hour. The 440-Hz tone, in addition to being a musical pitch standard, can also be used to provide an hourly marker for chart recorders, or other automatic devices.

Announcement segments of forty-five seconds' duration are available on a subscription basis to other Federal agencies to disseminate official and public service information. The accuracy and content of these announcements are the responsibility of the originating agency, not necessarily NBS.

Propagation forecasts. These useful forecasts, which occurred at 14 minutes past each hour, have been discontinued, some of the information contained in them has been transferred to the Geophysical Alerts segment of the format.

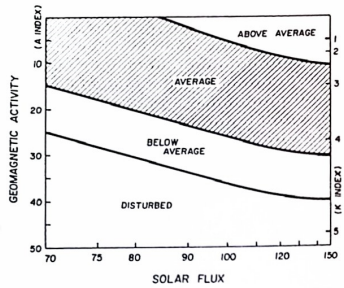


Fig. 4. Graph showing the relationship between Geomagnetic and Solar flux indexes, and their combined effect on ionospheric propagation of radio waves.

Geophysical alerts. Current alerts are broadcast in voice from WWV at 18 minutes after each hour, and from WWVH at 45 minutes after each hour. The messages are changed daily at 0400 UTC with provisions to

Table 1. High-frequency time and frequency-standard stations, listed by callsign.

Callsign	Location	Carrier Frequency (MHz)	Modulation*
ATA	New Delhi, India	10 & 15	1000 Hz + voice
CHU	Ottawa, Canada	3.330, 7.335 & 14.670	Voice
FFH	Paris, France	2.5	—
IBF	Rome, Italy	5	—
JJY	Tokyo, Japan	2.5, 5, 10, & 15	1000 Hz + voice
LOL	B. A., Argentina	5, 10 & 15	440 & 1000 Hz + voice
MSF	Rugby, England	2.5, 5, & 10	Voice
OMA	Prague, Czech.	2.5	1000 Hz
RAT	Moscow, USSR	2.5 & 5	10-second pulses
RCH	Tashkent, USSR	2.5	10-second pulses
RIM	Tashkent, USSR	5 & 10	10-second pulses
RWN	Moscow, USSR	10 & 15	10-second pulses
VNG	Lyndhurst Australia	4.5, 7.5, & 12	1000 Hz
WWV	Fort Collins Colorado, USA	2.5, 5, 10, & 15	440, 500, 600 & 1000 Hz + voice
WWVH	Kehaha, Hawaii	2.5, 5, 10, & 15	440, 500, 600, & 1200 Hz + voice
ZUO	Olifantsfontein, South Africa	2.5 & 5	—
GBR	Rugby, England	15.95 & 16 kHz	—
HBR	Pragins, Switzerland	75 kHz	—
JJF-2	Chiba, Japan	40 kHz	—
WWVB	Fort Collins Colcrado, USA	60 kHz	—

*All stations broadcast basic one-second time pulses, but some have additional modulation, as indicated.

provide real-time data alerts of outstanding geophysical events. These are followed by a summary of selected solar and geophysical events during the previous 24 hours.

Among the various events of interest to Radio Amateurs for purposes of following radio propagation conditions, are the Solar Flux and the Geomagnetic *A* Indexes. For best propagation of radio signals on the high-frequency bands, a relatively high Solar Flux and low geomagnetic *A* Index are desirable. The Solar Flux is measured at 2800 MHz and consists of radio "noise" whose magnitude has proven to be analogous to the magnitude of the energies that excite the *E* and *F* layers of the ionosphere. Solar-flux magnitude ranges from about 68 to 150, and can be roughly equated to smoothed sunspot numbers and MUFs.

The Geomagnetic Activity *A* Index indicates how well the ionosphere has performed with respect to the reflection and/or absorption of radio signals, particularly in the polar regions. An *A* Index of 0-7 means excellent reflection of signals, whereas an Index of 50 or over would indicate that a major magnetic storm is taking place with severely disturbed, if not disrupted, radio propagation conditions. In-between values indicate the relative condition of the earth's electromagnetic field.

This building is where the low-frequency transmitters, for stations WWVB and WWVL, are located. The towers support large wire antennas, but the largest is out of the photograph to the left. Prospective visitors should check with the US Department of Commerce in Boulder, Colorado, about the availability of tours at the WWV transmitting site (*photo courtesy US Department of Commerce*).

The Solar *K* Index is also given on the 18-minute after the hour broadcasts, and is updated every six hours. The *K* Index ranges from 0 to 9 and corresponds to the *A* Index from 0 to 50, respectively.

Fig. 4 shows the relationship between the various indexes and expected radio propagation conditions.

Marine storm warnings. At 8, 9, and 10 minutes after each hour, weather information about major storms in the Atlantic and eastern North Pacific oceans is broadcast in voice by WWV. Similar storm warnings covering the eastern and central North Pacific are given from WWVH at 48, 49, and 50 minutes after each hour. Additional one-minute segments at 11 minutes after the hour (WWV) and 51 minutes after the hour can be utilized under unusually severe

The building for WWVH in Hawaii is no less neat and functional than its stateside counterparts (*photo courtesy US Department of Commerce*).

widespread storm conditions. The brief messages are designed to tell mariners about storms in their areas. If no storms exist, that information will also be given. The ocean areas for which the U. S. has warning responsibility have been delegated by international agreement.

The National Weather Service issues regular broadcasts at 0500, 1100, 1700, and 2300 UTC from WWV; and 0000, 0600, 1200, and 1800 UTC from WWVH. These broadcasts are updated effective with the next-scheduled announcement following the time of issue.

Silent periods. These are periods with no *tone* modulation, but with continuing carrier frequency, seconds' pulses, time announcements, and 100-Hz BCD time code. The main silent periods extend from 45 to 51 minutes after the hour on WWV and from 15 to 20 minutes after the hour on WWVH. An additional 3-minute period from 8 to 11 minutes after the hour is silent on WWVH.

BCD time code

A binary-coded decimal (BCD) time code is transmitted continuously by WWV and WWVH on a 100-Hz subcarrier, and provides a standard timing base for scientific observations made simultaneously from different locations, such as astronomical events for example, or signals telemetered from satellites, where time markers superimposed directly on the recording aids data analysis.

UT1 time corrections

The UTC time scale broadcast by WWV and WWVH runs at a rate that is almost perfectly constant because it is based on ultra-stable atomic clocks, and meets the needs of most users. Somewhat surprisingly, some users of this service need time signals that are not this stable. For navigation and satellite

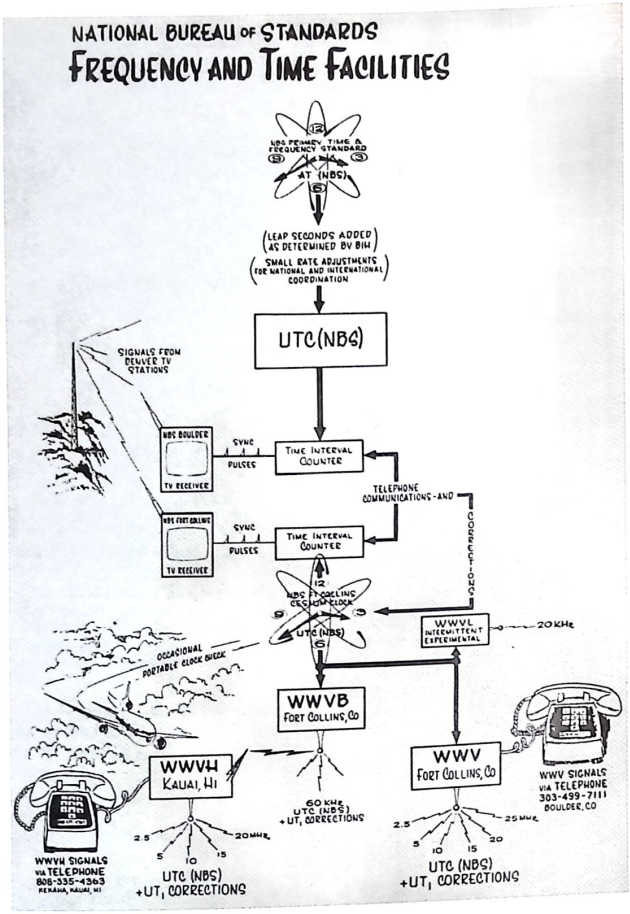

NATIONAL BUREAU OF STANDARDS
FREQUENCY AND TIME FACILITIES
NBS PRIMARY TIME & FREQUENCY STANDARD AT (NBS)
LEAP SECONDS ADDED AS DETERMINED BY BIH
SMALL RATE ADJUSTMENTS FOR NATIONAL AND INTERNATIONAL COORDINATION
UTC(NBS)
SIGNALS FROM DENVER TV STATIONS
NBS BOULDER
TV RECEIVER
SYNC PULSES
TIME INTERVAL COUNTER
TELEPHONE COMMUNICATIONS - AND - CORRECTIONS
NBS FT. COLLINS
TV RECEIVER
SYNC PULSES
TIME INTERVAL COUNTER
NBS FT. COLLINS CESIUM CLOCK
UTC (NBS)
WWVL INTERMITTENT EXPERIMENTAL
20 KHz
OCCASIONAL PORTABLE CLOCK TRIPS
WWVB FORT COLLINS, CO
WWVH KAUAI, HI
60 KHz UTC (NBS) +UT1 CORRECTIONS
WWV FORT COLLINS, CO
WWV SIGNALS VIA TELEPHONE 303-499-7111 BOULDER, CO
WWVH SIGNALS VIA TELEPHONE 808-335-4363 KEKAHA, KAUAI, HI
2.5 5 10 15 20 MHz
UTC (NBS) +UT1 CORRECTIONS
2.5 5 10 15 20 25 MHz
UTC (NBS) +UT1 CORRECTIONS

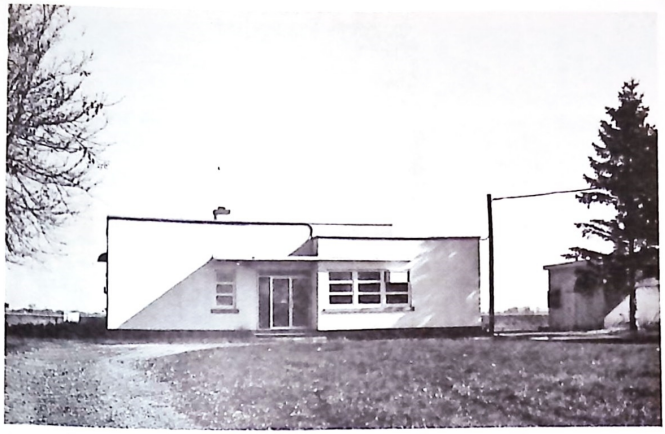
Fig. 5. The NBS frequency-control system.

tracking purposes, a time scale that slows down or speeds up with the earth's rotation must be used. The particular time scale needed is known as UT1 (inferred from astronomical observations) and is included in the UTC broadcasts at two levels of accuracy.

For those who need to know UT1 to only within about one second (most navigators), occasional corrections of exactly one second are inserted into the UTC time scale to keep UT1 and UTC time within plus or minus 0.9 second of each other. The correcting second insert is called a *leap second* and performs a function similar to that provided by the missing day every four years called *leap year*. As mentioned previously, the BIH regulates and coordinates the use of the leap second by international time and frequency broadcasting stations and bureaus of standards.

WWVB

WWVB transmits continuously on a standard radio carrier frequency of 60 kHz. Standard time signals,



The main building, left, and generator building, right, for time and frequency station CHU, in Canada (*photo courtesy Canadian National Research Council*).

time intervals, and UT1 corrections are provided by means of a BCD time code. The transmitting station is located on the same site as WWV, and effectively covers the entire continental United States. The frequency of WWVB is normally within its prescribed value to better than one part in 100 billion, and day-to-day deviations are normally less than 5 parts in 1000 billion. At this low carrier frequency, effects of the propagation medium on received signals are relatively minor; therefore frequency comparisons better than 1 part in 100 billion are possible by using appropriate receiving and averaging techniques.

WWVL

WWVL is an experimental station that broadcasts only on an intermittent basis, depending upon need and availability of funds. Transmissions can be made available on a subscription basis to public organizations and other Federal agencies.

Control of frequency

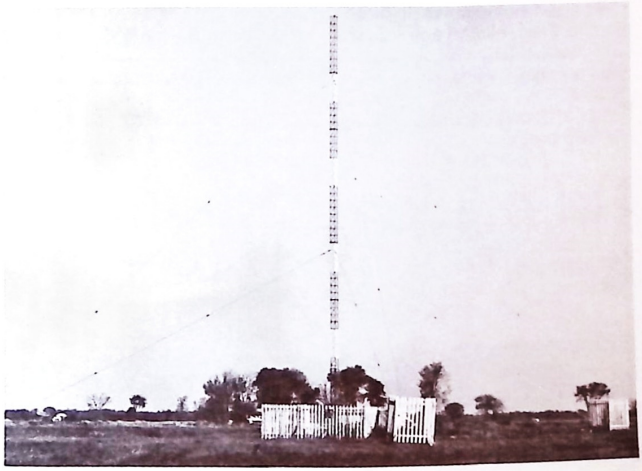
Fig. 5 is a simplified diagram of the NBS frequency control system, which depends upon the Primary Time and Frequency Standard. This standard includes a number of cesium-beam clocks, up to two primary cesium-beam frequency and time standards, and computer-aided measurement and computation methods which combine all of the clock data to generate an accurate and uniform time scale, called AT (UTC). Another scale, UTC (NBS), is also generated by adding leap seconds and small corrections to AT (UTC), as needed, to keep UTC (NBS) synchronized with the internationally-coordinated time scale, UTC, maintained by the BIH.

Canada — CHU

Astronomical observatories are always among the first facilities to generate and use accurate time information, furnished by daily — and nightly — observations of the sun, planets, and moons of our own solar system, as well as the stars of other systems. So it was in Canada, where radio time signals were first broadcast by radio during 1927 from the Dominion Observatory in Ottawa; although time signals had been sent over telephone lines from that source to the local Ottawa broadcast stations since 1923.

The first regularly broadcast transmissions from the Observatory were experimental, supplied by low-power battery-operated transmitters on wavelengths of 20.41, 40.82, and 90 meters because of their proximity to the bands used by Radio Amateurs, who at that time were the main users of "short" waves. In 1929 the

This is the antenna for 7335 kHz. The guys are fiberglass, believed to be the first such use in Canada (*photo courtesy Canadian National Research Council*).

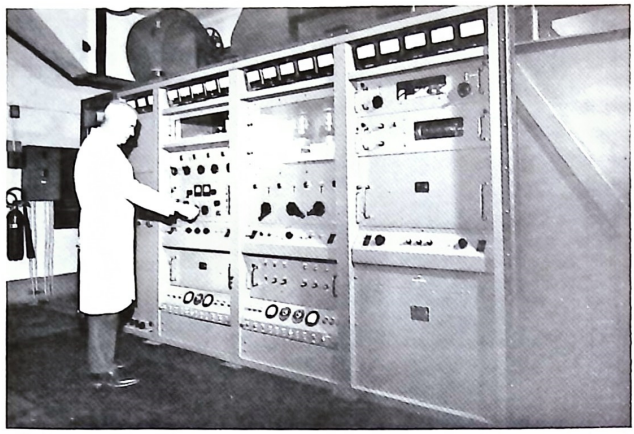


callsign VE9OB was authorized, and reasonably consistent, full-time transmissions began.

In 1942 the time service station was operating under the call CHU, using three 75-watt transmitters, with the call identified in Morse code. In 1946, power was increased to 500 watts, and in 1954, recorded voice announcements replaced the code. These, as well as the time signal pulses, originated in the Observatory and were sent to the transmitter site — approximately ten miles away — over telephone lines.

During 1960, a completely self-contained system was developed and installed at the transmitter site. The system consisted of relatively stable crystal oscillators which provided the basic source for synthesizing the three operating frequencies: 3330, 7335, and 14670 kHz. The crystal oscillators also provided the source for operating the synchronous motor-driven clocks which controlled the time signal. At the same time an automatic recording for the voice announcement was installed.

In 1963 the crystal units were replaced by an atomic frequency standard, and the electro-mechanical clocks by solid-state digital units. In 1964 English-French language voice



The 40-kW, 7335-kHz, transmitter at CHU. VE3BCL at the controls (*photo courtesy Dominion Observatory*).

drums were installed, and the present identification established. On April 1, 1970, the Canadian National Research Council assumed responsibility for Canadian time services, including the operation of CHU.

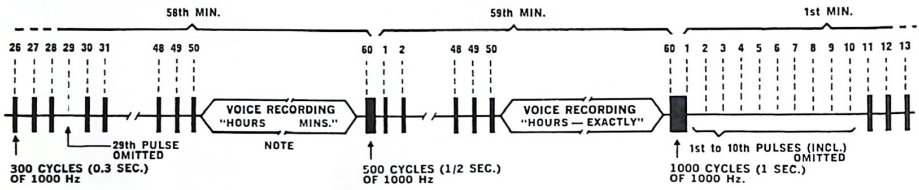
Who uses CHU?

The first users of CHU's services were scientific and survey parties. In fact, the initial "wireless" transmissions from the Observatory were made to a nearby field seismological station to coordinate field results with those obtained at the Observatory. Since those early days, gradual but steady improvements in consistency of service, accuracy of information, and output power have increased the usefulness and range of CHU to a point where anyone possessing even the most inexpensive short wave receiving set can use the Time Service.

Data transmitted by CHU

The broadcasting format of CHU is shown in **Fig. 6**. Three types of information are provided: Standard frequency,

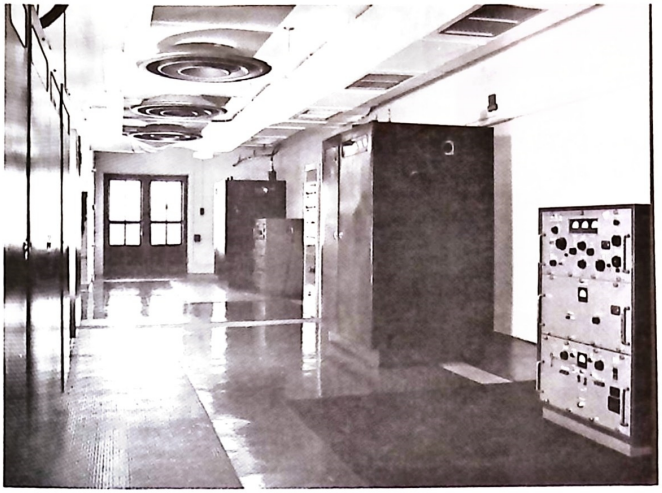
Fig. 6. CHU Data transmission sequence (*information courtesy Canadian National Research Council*).


58th MIN.
59th MIN.
1st MIN.
26 27 28 29 30 31
48 49 50
60 1 2
48 49 50
60 1 2 3 4 5 6 7 8 9 10 11 12 13
VOICE RECORDING "HOURS MINS."
VOICE RECORDING "HOURS — EXACTLY"
29th PULSE OMITTED
NOTE
1st to 10th PULSES (INCL.) OMITTED
300 CYCLES (0.3 SEC.) OF 1000 Hz
500 CYCLES (1/2 SEC.) OF 1000 Hz
1000 CYCLES (1 SEC.) OF 1000 Hz.

NOTE: VOICE RECORDINGS ALTERNATE IN FRENCH AND ENGLISH:

"CHU CANADA, EASTERN STANDARD TIME	HOURS	MINUTES	HEURES	MINUTES"	(EVEN MINUTES)
"CHU CANADA, HEURE NORMALE DE L'EST	HEURES	MINUTES	HOURS	MINUTES"	(ODD MINUTES)
"CHU CANADA, EASTERN STANDARD TIME	HOURS EXACTLY"		HEURES PRÉCISES"		(ON THE HOUR)

CHU IS LOCATED ON THE SOUTH WEST OUTSKIRTS OF OTTAWA AT 45° 17' 47" N, 75° 45' 22" W.



Transmitters line both sides of the corridor. The small units on the right are standby transmitters, which have been replaced by higher-powered ones. An automatic monitoring and switching system is used to change to a standby transmitter in case of failure, and to sound an alarm to bring an operator to fix the trouble (*photo courtesy Canadian National Research Council*).

standard time, and a means of automatically updating compatible digital clocks.

Frequency. CHU's basic frequency source is a cesium atomic standard which is used to control the three broadcast frequencies to an accuracy better than a few parts of a cycle. It must be remembered, however, that broadcasts for precision calibration purposes are affected by signal propagation delays which vary depending upon the distance from the transmitter site, and by delays which occur in the display and receiving equipment itself. For example, when the National Research Council compares signals from WWV, Fort Collins, Colorado, with CHU's transmissions, a delay of seven milliseconds must be included in the calibration calculations!

Time. Eastern Standard Time is transmitted by CHU in the form of tone pulses identified by voice announcements in English and French. The time is based on the atomic second which *gains* on Universal Time at the rate of about one second per year. This is adjusted by one second, exactly, when required — usually on either December 31st or June 30th of each year.*

*Years ago, the measurement of time was based on rotation of the earth (Universal Time, UT) which was shown to lack uniformity. Astronomers then adopted the period of revolution of the earth around the sun for the year 1900 as the basis for the measurement of time, and called it *Ephemeris Time*. Ephemeris Time forms the basis for all astronomical calculations and forecasts, but is not readily available for day-to-day use.

As physical sciences developed, the pendulum yielded to the quartz clock and then to the atomic clock as the primary time keeper. Today, the cesium atomic clock is the primary source of accurate time measurement, because in 1967 the International Bureau of Weights and Measures defined the second as 9,192,631,770 periods of the radiation corrresponding to the transition between two hyperfine levels of the ground state of the cesium 133 atom. This offered a firm and unchanging basis for scientists of the world to standardize their previously varied measurements.

CHU today

CHU is celebrating its "Golden Anniversary" this year, and invites interested persons to visit the facilities, 15 miles (24 km) from the center of Ottawa, where station personnel will conduct them on guided tours of the installation.

Acknowledgements

Special thanks to Roger Beehler, Chief, Time and Frequency Division and Sandra L. Howe, Technical Assistant, Time and Frequency Services Section, National Bureau of Standards, for providing the information on which this article is based. Of particular interest are *NBS Special Publication 432, Report 267-3 (Rev. 76) Standard Frequencies and Time Signals,* and *NBS Technical Note 681, A Satellite-Controlled Digital Clock*, from which the information in this article was drawn.

Special thanks also to Dr. Costain, Director, and Mr. Syd Sheard — VE3BCL — Chief Engineer, Time and Frequency Section (CHU), National Research Council, of Canada, for making this information available to *Ham Radio Horizons*. The material presented in this article was drawn heavily from a document titled, *National Research Council — Radio Time Service CHU.* The remainder was obtained from *Service Bulletin B-27* and *Service Bulletin TF-B-59.*

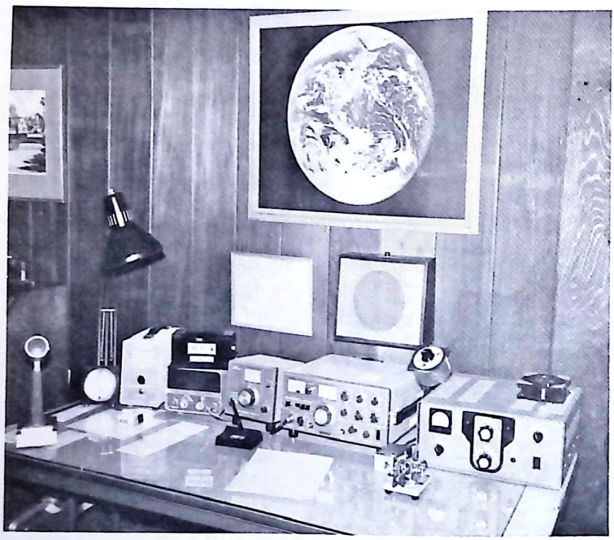
The Division of Physics of the National Research Council of Canada has published a comprehensive, illustrated, booklet in French and English titled *Standards of Time and Frequency in Canada*, which throughly discusses the cesium atomic clocks, how they are set up and maintained, and touches on future standards, plans, and techniques.

HRH

THE NOT-SO-ROCKY ROAD FROM CB TO HAM

Now is the Time to Take Your First Step on the Journey to Amateur Radio Where You'll Find Fun and Companionship. Here's an Overview of the Super Highway to Ham

BY JAMES H. GRAY, W2EUQ



So you're a CBer and want to become a ham? Great! Welcome to the fraternity of amateur radio. The full name of our hobby is the Amateur Radio Service, with emphasis on *service*; to each other, to beginners and to the community. Just ask a ham for help, and he is more than happy to be of service to you and anyone else who needs it. Radio amateurs, traditionally and with great pride, form the backbone of non-commercial communication in the world.

All that's necessary for you to begin is to have the desire; there's a huge world of communication opportunities out there just waiting for you to take part.

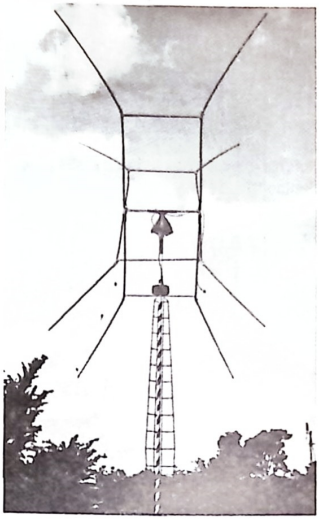
What can I do?

Rag chewing? You bet! And you are not limited to five minutes, either. Work DX? Sure; as much as you can rack up or have time for. In fact, DXing is encouraged and a whole branch of amateur radio operation is dedicated to working DX. Are you tired of being "rock-bound" or "channelized?" Then become a ham. Did you know that hams are legal "sliders?" Not only on one or two bands, but on all of them. In fact, if you don't use a vfo, you're old-fashioned!

Until recently, when seventeen new channels were granted to the Citizen's Radio Service, the CBer was restricted to just twenty-three channels. Now, even forty channels is limited in its ability to accommodate the communications burden, particularly when you consider that those channels are located in a small portion of the old eleven-meter amateur band, long a favorite of DXers among hams. On the other hand, amateurs are welcome to use many authorized bands ranging from our "top" band — 160 meters — lying just above the a-m broadcast band, to the ultra-high frequencies which are located above the TV channels. In between, we enjoy the use of the high-frequency bands: 80, 40, 20, 15, 10 and 6 meters — even 2 meters, which is technically a vhf band; all having different "personalities" and communications capabilities.

Learning is fun, too

Are you concerned about the



The beginning amateur can improve his signal by using a beam antenna. The cubical quad is a simple, inexpensive, and very effective beam that can be built from readily available materials.

"code," and do you worry about passing theory? Well, you can quit worrying, a five-year-old boy in Vincennes, Indiana did it last summer and is now on the air as WN9VPG — a Novice Class amateur. If he did it, you can too! Another thing: there's no age limit to becoming a ham, and — what's more — you are permitted to operate your amateur radio station in other countries under a program called reciprocal licensing, sponsored by our government and the governments of cooperating countries. Under this program, their hams can operate here, too.

Besides, you wanted to learn something about communications, didn't you? You've outgrown the "10-4 good buddy" routine and want to progress to a greater understanding of what it's all about, right? Okay, then ham radio is made for you.

Nuts, bolts and screws

How about equipment? Isn't it expensive? No more so than CB radios, really, when you consider what you get for your money. Most popular transmitters, receivers and transceivers are equipped to operate on five different amateur bands, 80 through 10 meters, at a price comparable to that of a good CB radio; and at higher power, too!

You fellows out there with Yaesu transceivers, for example, don't even have to buy any new gear; you can be ready to operate on the ham bands as soon as you're licensed. You might also think about getting on the air with good *used* equipment for much less than the price of a new CB radio; with the added advantage of a vfo, plus world-wide communications capability at power levels of several hundred watts.

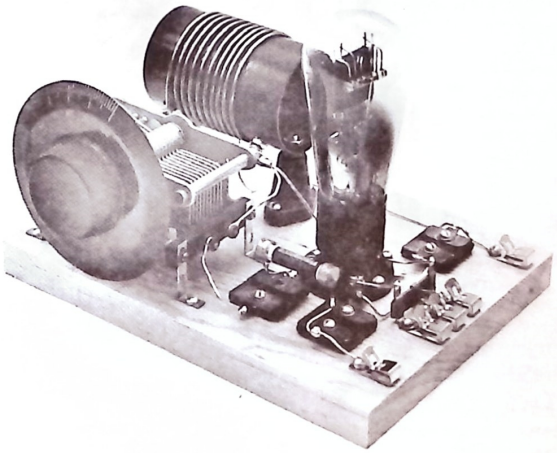
Sure, the ham rig can cost a cool Kilobuck or two, but it doesn't have to; it could cost as little as a couple of Centibucks — depending on what you can afford and how good a "wheeler and dealer"you are. Point is, you don't need the most expensive radio to get started, and you won't be taking a back seat, either. Some of the best signals around are put on the air by Novices running less than 100 watts and using "ancient" tube-type equipment.

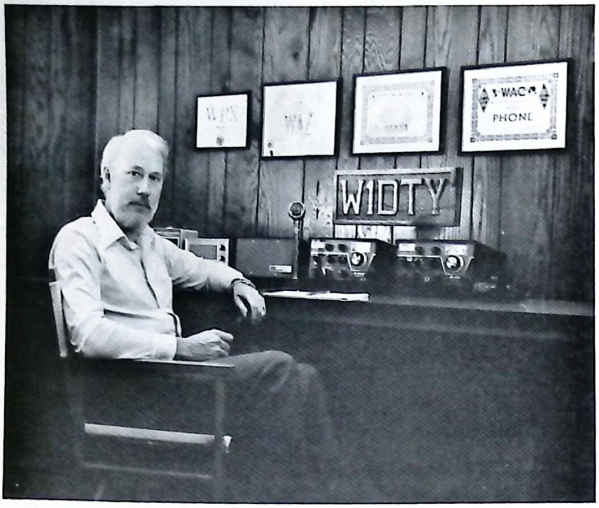
By the way, in case you hadn't heard, Novices can now run 250 watts of input power to the final amplifiers of their transmitters; more than enough to communicate with any country in the world under normal circumstances and conditions. Hams tend to do it with finesse, not force; but — when you need power, General and higher class licensees can *legally* run a kilowatt!

Begin at the beginning

Oh, I know: you don't have time for all that study and practice, right? *Wrong*! If you can spare 15 minutes a day to work on the code and another 15 minutes each day on the theory, you could have your

Single No. 45 tube transmitter, built by W6SAI from parts taken out of a defunct receiver and arranged in a Hartley circuit, cost little or nothing to build but gave a good account of itself on CW in 1976 — just as the original did in 1930. Note simple breadboard construction, direct wiring, hand-wound coil. However, with exposed circuits, television interference could be a problem. In 1930 hams didn't worry about that!





Modern amateur station of W1DTY is capable of worldwide communication and includes transmitter, receiver, electronic keyer, microphone, dummy load for tuning without placing signal on the air, and — of course — the operator.

Novice ticket (well, at least be ready for the exam) in a month; and be ready for the General Class license exam in three months.

Rules and regulations for the birds? Wrong again. Amateur radio operators represent the largest self-regulated and disciplined group in all of radio. Sure it's a hobby, and a darned good one, but the name of the game is responsibility. Just show "Uncle" that you can play the game fair and square, and he'll respond by giving you the freedom you want and need. Rules and regs are common-sense simple, and boil down to one underlying theme: respect and non-interference. Respect of the other ham's right to use a frequency on a non-exclusive basis — just like you have the same right; and the willingness to let him use it without interference if he's there first. If the frequency is busy, slide! That's legal, in ham radio.

What's in it for me?

You may wonder what you're going to get out of all this, and the answer is — fun; FUN, in capitals. Hamming is a way of doing your own thing, and there's more to do than you ever dreamed possible. Traffic nets for one thing; where you send, receive, and relay messages all over the United States, and many countries — free! Part of that word *service*, again.

There is experimentation and building; all perfectly legal and, in fact, encouraged because it is instructive and it's part of the tradition that has made ham radio what it is today. Build your own equipment? Certainly! It's done all the time by beginners and old timers alike. *Ham Radio Horizons* will tell you how to do just that, with minimum chances for mistakes or costly trouble. Even if you goof, so what? That's part of learning, too.

There's the opportunity for public service through Civil Defense, Red Cross, disaster and preparedness communications and many others.

You'll find education and training, the business of helping others like yourself get started on the right foot; and there's challenge. Reminds me of the time I was in Oklahoma City, and I asked a little old

For many hams, operating brings its awards and fun. Among the most sought-after awards is the WAS — Worked All States — certificate issued by ARRL, the American Radio Relay League. All that you need to do is submit proof that you have made a two-way contact with another ham in each of the fifty United States. QSL cards are the best proof available.

wizened-up bell hop at the hotel: "What's to do in Oklahoma City, Pop?" Quick as a flash he snapped back: "Anything you're *man* enough to do, Son!" And that pretty well sums it up: the challenge to get busy and do something with ham radio. The most important letter in fun is "u," spelled y-o-u!

You can participate in hamfests, in field-day exercises and in many different types of contests. Some hams are trying to contact all of the counties in the United States, others are trying to work all of the states in the U.S.A., while still others are well on their way to achieving contacts with every country in the world recognized in the "DX countries list." They call it certificate hunting, but we call it fun — all a part of the fine art of hamming. As you do these things, and many more, you'll be talking to other hams, improving your operating skills, and gaining knowledge; even better — understanding.

Have you heard about OSCAR? No, it's not a ham — it's a satellite. That's right, radio amateurs have their own satellites; not one, but *two*! The acronym stands for *O*rbital *S*atellite *C*arrying *A*mateur *R*adio. The first OSCAR, way back in December, 1961, was a small box-like package that went beeping around the globe sending code letters that translated to HI — HI, the ham's abbreviation for laughter. Each succeeding OSCAR, and we're up to seven of 'em at last count, has carried improved communications capability. The latest ones, OSCARs Six and Seven, regularly serve as repeaters; accepting signals from earth and rebroadcasting them on another, and usually lower, frequency.

Hams all over the globe have communicated with each other via OSCAR, and still do it on a daily basis. OSCAR eight will be lofted some time before 1980, launched into an eccentric orbit that will permit amateurs to have several hours of access on each "pass," rather than the present few minutes available with OSCARs Six or Seven in their essentially circular orbits. Equipment needed is modest, and the antenna is probably the most important item you'll need. In future issues we'll offer simple and inexpensive equipment for you to assemble for the purpose of "accessing" OSCAR. Sound like fun? You bet it is, and represents just another of the many new, different, and interesting aspects of our amazing hobby.

Modes and means

There is mobile and fixed-station activity carried on by hams using a variety of modes: a-m, fm, ssb, CW, ATV and RTTY — even FAX, or facsimile. Now the field of amateur computers and calculators — microprocessors — attracts and ensnares the amateur experimenter. In short, there is more to do and more to be done than ever before, and all of it is waiting for you to take the first step.

How do you get started? That's easy, too. By reading this article, you've already begun your journey on the road

This little battery-powered receiver covers the Novice portions of 40 and 80 meters. Built from inexpensive parts,the receiver features a true superheterodyne circuit, with excellent sensitivity and selectivity. Could be a companion unit for the flea-power transmitter in the following photograph. Constructing and operating your own equipment is lots of fun.

This small four-band homemade QRP transmitter uses readily-available crystal oscillator circuits and features a built-in whip antenna with a tuning unit to radiate its one watt of power. Despite its size, this little rig can be used to send signals for hundreds of miles. A battery power supply and hand key mounted on base board complete this fine portable and emergency station.

On-the-air shot of W9NTP. Here, Don adjusts the slow-scan monitor of his amateur television station. The camera is at upper right. Station can be assembled at modest cost using some surplus and some homebuilt equipment. New equipment for ATV stations is also available from suppliers of amateur radio gear. Amateurs all around the world can communicate via slow-scan TV.

Joe DelPrincipe is a junior at New York State University College at Fredonia, and an active radio amateur. He holds the amateur Extra Class license and is a member of the Navy's Military Affiliate Radio Service (MARS) teletype network. Joe's room is his communications center where he spends up to four hours a day relaying messages, primarily from servicemen to their families, through his station. Joe has been a ham since he was a senior in high school, and much of the equipment shown here has been built from kits from scratch or rebuilt by Joe in his spare time — including the "junk" teletype machines donated by the Navy. Joe exemplifies service to the public through his hobby — amateur radio.

to HAM. A next step might be to find a local amateur radio club in your town or city — or even an individual — a licensed ham in your neighborhood. Just show a sincere interest and a desire to learn more. Ask his help; he'll find your request irresistible.

"Mother, you can't expect him to fix a leaky faucet when he's just bounced a signal off the moon!" Many hams are active in EME, earth-moon-earth, communication. In fact, a recent *moonbounce* expedition to Colombia, South America, set new records for distances and number of stations worked.

Service with a smile

Remember we've been talking about service? Well, part of the amateur's service to his hobby is getting others started and on the air. I'll admit that some "dyed-in-the wool" hams start out by being prejudiced against CBers, but I'll bet that you know more than one CBer who feels the same way about hams. Okay, that's bound to happen, and there's argument on both sides to support this attitude; but it isn't widespread, and I know lots of hams who are actively recruiting Citizen's Banders into the ranks of amateur radio. On the other side of the coin, many hams are avid CBers and will continue to be in order to take advantage of the very real benefits the band has to offer.

First, you'll have to learn to send and receive five words per minute of International Morse Code, and be able to pass a written test of 20 questions about simple electrical principles, FCC rules, and operating practices for amateur Novice Class stations. If you already know that an Ohm is a unit of electrical resistance, that QSL means confirmation of a contact, and that "blue" language is prohibited, you're already on your way to becoming a ham.

Who's on first?

To make it even easier for you to get started, perhaps joining with four or five others who want to become amateur radio operators, *Ham Radio Horizons* has an introductory package of learning materials that you can order and use — even alone, if necessary. The code lessons are on tape and the book includes a sample FCC-type theory examination. You don't even have to go to the nearest FCC office to take the examination; a licensed amateur can give you the test in your home or his, provided that he holds a General — or higher class — amateur license.

Feminine amateurs? Of course; many are on the air and taking part in those ham

Slow-scan amateur television pictures have excellent quality, as evidenced by this picture transmitted on 14 MHz by W4CCG, Manassas, Virginia and received by W8SH, East Lansing, Michigan. The television pictures you receive at home on your commercial set are called fast-scan, but can be sent or received in the slow-scan mode with an appropriate converter.

activities that most interest them. They have their own clubs, nets, and even a national organization of dedicated "YLs."

The "green stamp"

You'll discover the road to HAM a broad highway to fun and adventure, with various and interesting side roads to explore, all leading to development of your ability to communicate by radio. At every turn you'll find opportunity to go places, meet people, and do things that you may never have realized existed. The horizon is unlimited, you can go as far and as fast as you like: it's "clean and green" all the way.

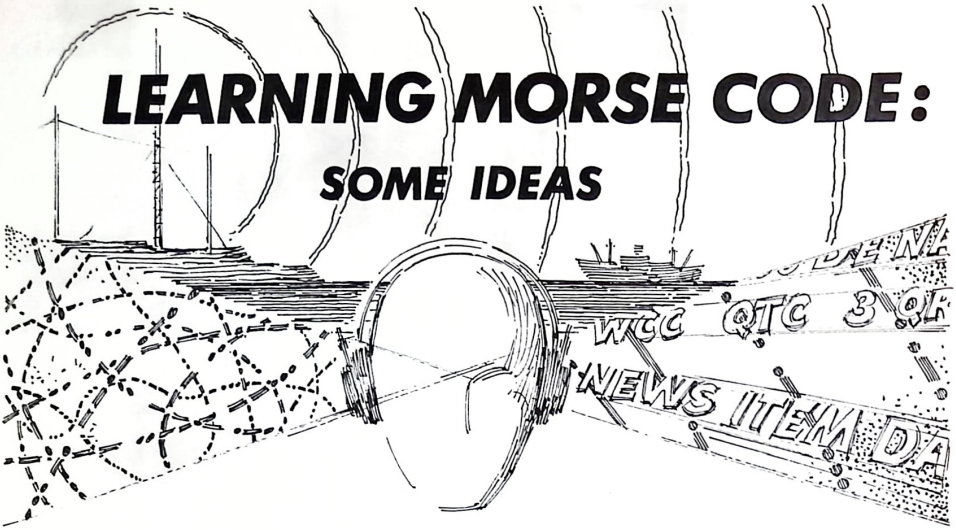
Mile markers are the Novice, Technician, General, Advanced, and Extra Class amateur licenses; each reflecting a bit more skill and knowledge on the road to HAM. As you might expect, more privileges and greater freedom go with each marker along the way — and more responsibility, too.

Why don't you join our convoy now? Remember, you'll never be able to start any sooner, and each journey begins with a single step. Write "I Want to be a Ham," *Ham Radio Horizons,* Greenville, New Hampshire 03048. We'll send you a catalog and suggested list of study materials to start you on your way.

HRH

"I wish you'd learn to control your temper, Ralph. Remember, you were a CBer, too!"

LEARNING MORSE CODE: SOME IDEAS



BY ALFRED WILSON, W6NIF

Learning to copy and send Morse is much like learning to touch type. When you first start a class in touch typing, the instructor usually gives you a copy of the typewriter keyboard with a diagram that shows what fingers are to be used to type each character. The row of keys on the machine starting with the letter *A* and ending with @ is called the "home row." You are then instructed to learn the typewriter keyboard by first typing *ASD* with your left hand and *JKL* with your right hand. You do this over and over and over again until you instinctively type these letters *without looking at the keyboard*. The remaining portion of the typewriter keyboard is learned similarly. Eventually, after hours of practice, you can sit down at any standard typewriter keyboard and type copy without looking at the keyboard.

This article, of course, isn't a lesson in learning to touch type, but rather a way to learn Morse code based on the repetitive principles used to learn how to handle the typewriter keyboard. The key (no pun intended) is *practice*. Many, many hours are required for some; for others, perhaps just a few hours.

Preliminary steps

You've heard that Morse is learned by sound rather than sight. You don't learn the Morse alphabet by memorizing "dot dash" for the letter *A* or "dash dot dot dot" for *B*, and so on. You must translate the Morse characters for each letter, number, and punctuation mark into sounds: "dit-dah" for *A*, "dah dit dit dit" for *B*, and so on through the alphabet.

In keeping with the repetitive principles of learning to touch type, start by learning the first three letters of the alphabet. Mentally sound out these three letters over and over again until you can irrevocably recognize each letter, however slowly. After sufficient practice you'll be able to have someone sound out these first three letters and you'll be able to write them down in any combination, without error, and without hesitation.

The next step, again in keeping with touch-typing principles of repetitive learning, is to get acquainted with the next three letters of the alphabet. (You've learned how to recognize *ABC* in all three combinations by now, and you'll never forget them — providing you've practiced sufficiently.)

Work with *D, E,* and *F* in the same way. Try copying various combinations, over and over again, until you can recognize each Morse character for these letters *without having to think about it*. Your brain and motor nerves will then be conditioned to operate as a system. Once learned, you'll never forget.

How to practice

One method I used to gain code proficiency proved quite helpful. It was many years ago when I was a youngster going to high school. I'd learned all the letters, numbers, and punctuation using the repetitive learning approach mentioned above. But my code speed was slow, slow, slow!

Perhaps 5 words per minute.

On the trolley car to school, I read all the billboard ads and mentally sent the words to myself in Morse. I'd look at a billboard, send the message to myself mentally, and wait for the next billboard. After about two weeks of this I was able to mentally recognize words, numbers, and punctuation without hesitation. With this new-found ability, the next step was to increase speed.

I didn't have any buddies to send Morse to me so I could increase my code speed. I did, however, have a general-coverage shortwave receiver. In those early days there were no code-practice transmissions by ARRL station W1AW. So I tried to build up my code speed by copying fellows on the 40-meter band. Sounds like a reasonable approach, but it didn't work — at least not for me. Too many guys with lead (I mean lead as in lead pipe) fists, too much interference (the band is even worse today), and unpredictable propagation conditions.

Then, one evening, I tuned my receiver upward in frequency past the 40-meter band and started listening to marine radio-telegraph stations, which operate between about 8.0 and 8.8 MHz. What a difference! I started copying ship stations sending messages to each other and to stations on the coastal shores of the U.S. No real problems with fading or interference!

Table 1. Where to find commercial ship and coastal radiotelegraph stations in the medium- and high-frequency shortwave spectrum.

Ship stations (frequency, MHz)	Coastal stations (frequency, MHz)
4.160 - 4.177	
4.187 - 4.238	4.238 - 4.368
6.240 - 6.265	
6.281 - 6.357	6.357 - 6.525
8.320 - 8.354	
8.374 - 8.476	8.476 - 8.745
12.471 - 12.531	
12.561 - 12.714	12.714 - 13.130
16.622 - 16.706	
16.748 - 16.952	16.952 - 17.290
22.148 - 22.220	
22.270 - 22.400	22.400 - 22.650

Table 2. Selected list of coastal marine radiotelegraph stations operating in the 8-MHz band. These stations will be found just above the 40-meter Novice amateur band on a general-coverage shortwave receiver.

Station	Frequency (kHz)	Power (kW)	Location
WMH	8502	0.75	Baltimore
WSL	8514	2.5	New York
WAX	8526	3.0	Ojus, Florida
WPA	8550	3.0	Port Arthur, Texas
KFS	8558	10.0	San Francisco
WNU	8570	2.0	New Orleans
KLB	8582	2.5	Seattle
WCC	8586		Chatham, Massachusetts
KOK	8690	10.0	Los Angeles
WSC	8610	20.0	Tuckerton, New Jersey
KPH	8618	10.0	San Francisco
WCC	8630		Chatham, Massachusetts
KPH	8642		San Francisco
WSL	8658	10.0	New York
KBL	8658	2.5	Seattle
KLC	8666	2.0	Bremerton, Washington
WSC	8686	2.0	Tuckerton, New Jersey
WMH	8686	0.75	Baltimore

The marine coastal stations are in business to make money, of course, so they operate on clear channels with substantial power and are manned by operators who are real pros. These fellows don't horse around, believe me. They send Morse code, perfectly and impeccably, and gear their sending to prevailing conditions.

All in all, I recommend using coastal and ship stations, operating in the CW commercial bands, as sources for code practice. You can hear all sorts of stuff from the coastal stations that should provide code practice for whatever level your code speed is. You'll find newspress items (generally sent at speeds around 20-25 wpm); weather transmissions (between 15 and 25 wpm); messages to ships at speeds ranging from 5 to 35 wpm, depending on conditions. Some of the coastal stations ops use electronic keyers, some use the dash side of a bug, some sound as if they're using a heavy foot pushing a trapdoor. But in every case, the Morse is generally perfect. Characters are formed so that there's no doubt as to the letter or number being sent. If propagation conditions are not good, the coastal station operators repeat words or sentences.

After you gain a little proficiency in handling code, listening to the stations on the marine radio telegraph shortwave bands can be a lot of fun. For example, the other day I was listening to a west-coast coastal station trying to work a foreign-ship station. Seems that the ship's operator was having problems receiving the coastal station. After about ten minutes the foreign-ship operator said, "Mucho QRM, OM. Tomorrow is another day, OK?"

Where to find them

The accompanying tables will help you find the marine stations on your general-coverage receiver. **Table 1** lists frequencies of ship and coastal stations in the shortwave marine bands. In **Table 2** you'll find information on commercial coastal stations and their locations. Most of the latter stations run a lot of power, so you should be able to find them without any trouble, even if you use a wet noodle for an antenna.

HRH

Radio-Station And Radio-Operator Licensing

Although the administration of licensing and regulating all classes of radio stations and radio operators is left to the governmental agencies of each country, most countries adhere to a treaty which was set up by the International Telecommunications Union. The Radio Regulations which were drawn up by the ITU define the various services in broad terms, and allocates portions of the radio spectrum for these services in the various parts of the world. These portions are not necessarily uniform, and some countries are not signatory to the treaty. In general, the ITU Radio Regulations do prevent the communications world from being complete chaos, and provide a vehicle for agreements between nations in order to prevent complete disruption of radio services on a world-wide basis. Radio signals in the high-frequency range propagate to all parts of the globe, and no national or continental boundaries can stop them.

The amateur service is recognized in the ITU Geneva Radio Regulations as follows:

> *Amateur Service*: A service of self-training, intercommunication, and technical investigations carried on by amateurs, that is, by duly authorized persons interested in radio techniques solely with a personal aim and without pecuniary interest.

Other items from the Radio Regulations that concern amateurs are covered in Article 41.

Article 41 — Amateur Stations

Section 1; Radio communications between amateur stations of different countries shall be forbidden if the administration of one of the countries concerned has notified that it objects to such radio communications.

Section 2; 1) When transmissions between amateur stations of different countries are permitted, they shall be made in plain language and shall be limited to messages of a technical nature relating to tests and to remarks of a personal character for which, by reason of their unimportance, recourse to the public telecommunications service is not justified. It is absolutely forbidden for amateur stations to be used for transmitting international communications on behalf of third parties.

2) The preceding provisions may be modified by special arrangements between the administrations of the countries corncerned.

Section 3; 1) Any person operating the apparatus of an amateur station shall have proved that he is able to send correctly by hand and to receive correctly by ear, texts in Morse code signals. Administrations concerned may, however, waive this requirement in the case of stations making use exclusively of frequencies above 144 MHz.

2) Administrations shall take such measures as they judge necessary to verify the technical qualifications of any person operating the apparatus of an amateur station.

Section 4; The maximum power of amateur stations shall be fixed by the administrations concerned, having regard to the technical qualifications of the operators and to the conditions under which these stations are to work.

Section 5; 1) All the general rules of the Convention and of these Regulations shall apply to amateur stations. In particular the emitted frequency shall be as stable and as free from spurious emissions as the state of technical development for such stations permits.

2) During the course of their transmissions amateur stations shall transmit their call sign at short intervals.

In many parts of the world, communications is a monopoly held by the governmental agencies, therefore restrictions have been placed on the handling of messages by amateur stations — especially when the messages are for or from a third party. (The two amateur-radio operators in contact with each other are the first and second party; anyone other than these two is a third party, even though it be a relative or friend in the immediate presence of the licensed amateur-radio operator.)

With these restrictions in mind, and considering the differences in licensing structure in the various countries, we can only present the details of amateur licensing as currently in force in the United States. Many countries permit reciprocal operation by visiting amateurs, and the time required to obtain this permission varies from days to months. Procedures should be checked well beforehand. Information is usually available at International Amateur Radio Union (IARU) headquarters, C/O ARRL, 225 Main Street, Newington, Connecticut 06111. They often can advise about the correct person or department to contact for minimum delay.

Because the amateur rules and regulations do not remain constant, especially at this time, just before a World Administrative Radio Conference of the ITU, a Bibliography of material that will keep you up to date on amateur licenses, and will help study for the exams, is given at the end of this section.

Here, then, is a summary of the United States Amateur Radio licenses, requirements, and privileges.

Amateur License Classes And Privileges

Novice Class — Examination consists of questions about basic radio theory, FCC rules and regulations, and a test of your ability to copy International Morse code at a speed of 5 words per minute. Examiners may or may not require that you demonstrate proficiency in sending Morse code. The exam may be administered by a volunteer examiner who is over 21 years of age, holder of an amateur General class (or higher) license, and is not related to the person taking the examination. Persons who hold a Commercial Radiotelegraph second class (or higher) license, or who are employed by the United States as operator of a radiotelegraph station, also may administer the

examination. The license is for a term of two years, and is non-renewable. However, it may be reissued upon passing a new examination. Privileges are granted to Novices to use Morse code only, in segments of the amateur high-frequency bands, namely, 3700-3750 kHz; 7100-7150 kHz; 21.1-21.2 MHz; and 28.1-28.2 MHz. Power input to the final stage of the transmitter is limited to 250 watts.

Technician Class — Designed for the experimenter type of amateur, it requires a more detailed written examination. Questions cover general theory and applications, rules and regulations, and construction and operating techniques. The code test is the same as for Novices. The exam is given by FCC officials and employees only. The license term is for 5 years, and is renewable. Privileges include the ability to use any transmission mode permitted on the vhf bands of 50.1-54.0; 145-148 MHz; and all privileges above 220 MHz. Additionally, Technician-class licensees are permitted all Novice privileges as given above.

General Class — This is the most popular amateur license. It requires a general theory and practice examination which is the same as the written examination for the Technician-class license. The code test is at 13 words per minute. The examination is given by FCC personnel only, except in the case of bona-fide hardship cases or physical disability that is attested to by a physician. In these cases, the exam may be administered by a volunteer examiner of proper license class and age. A license so obtained is called a "Conditional" license of whatever class it applies to. Any license from Technician through Extra may be obtained in this manner. Privileges include all modes available to amateurs on all amateur frequencies except for some small segments set aside for Advanced and Extra class licensees in the high-frequency amateur bands. The license term is 5 years, and is renewable.

Advanced Class — As the name indicates, this is for the more advanced technical person. The examination requires a deeper knowledge of theory and application in electronic circuitry, propagation, and operation. There is no additional code test required to upgrade from General to Advanced. The exam is given by FCC personnel only. The license term is for 5 years, and is renewable. Privileges are the same as for General class, with the addition of operation permitted in some high-frequency segments set aside for Advanced-class licensees.

Extra Class — This class is the top of the line, requiring an extensive knowledge of electronics in theory and practice. It is in many ways comparable to the Commercial Radiotelephone first or second class license. The exam also requires passing a sending and receiving test of International Morse code at a speed of 20 words per minute. The exam is given by FCC personnel only. Privileges are for all modes available to amateurs, on all amateur frequency bands. Some segments of certain bands are set aside for Extra-class licensees only. The license is for 5 years, renewable.

Modes of Operation By Amateurs

Generally speaking, amateurs can use any type of transmission known or practiced by anyone in the communications world. The only real prohibition is against one-way transmissions, except for certain types of informational bulletins or code-practice material. One-way transmission intended for the general public are considered broadcasting, and are forbidden in order to protect the Broadcasting Industry from unfair competition, and also to protect the amateur frequencies from commercial encroachment.

Otherwise, an amateur can find a place in the spectrum for any type of communication he wants to use. Narrow-band modes, such as Morse code, amplitude-modulation voice, some radio-teleprinter, slow-scan (limited definition) television, and narrow-shift frequency modulation is allowed in the high-frequency spectrum between 3 and 30 MHz. Modes that require more spectrum space are relegated to the higher bands, with wide-band frequency modulation permitted on many amateur frequencies above 52 MHz, regular high-definition television above 420 MHz, and types of pulse modulation on some of the microwave bands. Each of the bands below 1215 MHz is subdivided, by agreement or by FCC allocation, into segments for some of the more popular modes. A broad rule is that voice and other modulated modes are separated from the areas where Morse code is permitted.

Some of the vhf bands have portions set aside for the use of amateur repeater stations. Repeaters are located at locations that provide improved geographical coverage by their signal because of height above surrounding terrain. A receiver picks up a vhf signal from a mobile or hand-held unit, and feeds the signal into a transmitter to be amplified and retransmitted. In this manner, a low-powered transmitter can have its effective range increased by a factor of ten or more.

Maritime Mobile Operation

Since this booklet is intended to provide information to you who are boating fans, and many of your craft are capable of operating beyond the territorial jurisdiction of the United States, there are a couple of specific points worth calling to your attention.

First, a station that is operated aboard a craft

on rivers, streams, or lakes within the boundaries of the United States is *not* Maritime Mobile. It is simply *mobile*, if in motion or stopped temporarily. If the craft is at a mooring for an indefinite length of time, the station is *portable*. The designation of portable or mobile can be indicated when signing your call letters by saying "portable (or mobile) near (town or location)," or "portable (1, 2, 3, etc. designating call area)." This procedure is no longer required by FCC Rule, but is recommended as a courtesy to fellow amateurs.

Secondly, when you are outside the continental limits of the United States, you are Maritime Mobile, and should so state when identifying. You should also designate the region you are in, as indicated by **Table 1** on the inside back cover.

Further, note that Maritime Mobile operation is not permitted on the amateur frequency band 3.5 to 4.0 MHz. You may operate mobile or portable within the jurisdiction of a government that permits amateur operation on that band, if that government has reciprocal agreements to allow you to operate within its jurisdiction. The reason for this restriction is to be found in the allocations as indicated by **Table 1**. In some parts of the world this band is given to commercial or broadcast services, who do not want amateurs to interfere with their transmissions.

Although some of the restrictions may seem unnecessary, I'm sure you recognize that each government has a right to determine its own policies. You should be aware of what some of the differences are, just as you will undoubtedly check with authorities before sailing into a foreign port in order to find out what possible restrictions may be in force as to anchorages, facilities, or prohibited areas.

Bibliography

The following publications can provide information concerning amateur radio licenses, and material that you can study in preparation for the amateur examination. Unless noted, all are available from Ham Radio's Communications Bookstore, Greenville, New Hampshire 03048. When writing or ordering any of the publications, be sure to use the order number listed. Prices are those current in early 1978, and are subject to change.

Advanced and Extra Class Amateur License Q & A Manual, by Marvin Tepper, Hayden Book Company. FCC Rules and Regulations, theory, sample questions and answers with discussion. Order HA5917, price $5.95.

Amateur Radio License Study Guide, by Jim Kyle, K5JKX, and Ken Sessions, K6MVH, Tab Books. Individual study guides for each amateur license class. Order number for Novice is T-873; for Advanced, T-827; for Extra, T-543, price for each is $5.95. Study guide for General Class license is T-851, price $7.95.

Ameco Novice Package, Ameco Publishing Corp. A complete home study course, including *Amateur Radio Novice Theory Course*, a booklet on learning code, sample FCC exam, plus a tape cassette for code learning and practice. Order NP-1, price $6.95.

Ameco Radio Amateur Question and Answer License Guide, by Martin Schwartz, W2OSH, Ameco Publishing Corp. Novice and General rules and theory discussion in question and answer style. Practice questions in FCC multiple choice form. Order 5-01, price $1.00.

Electronic Communications, by Robert L. Shrader, McGraw Hill. A good all-around study guide and textbook for many phases of electronics. Covers General theory and practice for Commercial licenses as well as Amateur, and includes some sample questions for both services. Aside from its study applications, it is an excellent reference book for basic electricity and electronics. Order MH-57138, price $18.95.

Novice and General Class Amateur License Q & A Manual, by Marvin Tepper, Hayden Book Company. FCC rules and regulations, theory, sample questions with answers and discussion. Order HA-5599, price $6.95.

Rules and Regulations, Part 97, Amateur Radio Service, Federal Communications Commission. Available from the Government Printing Office. Stock Number 004-000-00338-1, price $1.30. May be ordered from the GPO in Washington DC, or from GPO Bookstores in major cities.

The Radio Amateur's License Manual, American Radio Relay League. FCC Rules and Regulations, theory, questions and answers starting with General or Technician level and including Advanced and Extra. Some discussion, with references to other texts for supplemental study. Order AR-LG2, price $3.00.

Tune In The World With Ham Radio, American Radio Relay League. Beginner's level material, intended for Novice examination study. Package includes promotional material for the amateur service, text and study booklet, map of United States call areas, and a tape cassette with some low-speed Morse code and samples of on-the-air contacts between amateurs. Order AR-HR, price $7.00.

As study material is brought up to date, and as license requirements change, our bookstore will stock the latest guides. For new information at any time, write for a free catalog to Ham Radio's Communications Bookstore, Greenville, New Hampshire 03048.

Ham Radio Horizons is a monthly publication for the beginner, for the non-ham who is interested in amateur radio, and for the not-so-technical amateur who enjoys participating in this great hobby. It is designed to show some of the interesting and delightful facets of amateur radio, and to aid people in becoming amateurs, or in improving their status in the amateur ranks. Material presented ranges from discussions of the latest devices and techniques in the communications field to some reminiscences of the "Golden Years" of our past. Recognizing that not all people will be reached by any given message, our writers present the basic tutorial material in several forms in order to fit the learning level of a maximum number of people. As the FCC requirements for licensing change, *Horizons* shifts its emphasis to cover the new ground. Whatever your interest or ability, *Horizons* is recommended as the publication to keep at hand. Subscription rate is $10 per year. Write to *Ham Radio Horizons*, Greenville, New Hampshire 03048.

Thomas McMullen, W1SL

Table 1. ITU Geneva Amateur Allocations Summary

Band	Worldwide	Region 1 (Europe-Africa)	Region 2 (N. & S. America)	Region 3 (Rest of World)
1800-2000 kHz	—	Fixed* Mobile	Amateur† Fixed Mobile Radionavigation	Same as Region 2
3500-4000 kHz	—	3500-3800 Amateur Fixed Mobile	3500-4000 Amateur Fixed Mobile	3500-3900 Amateur Fixed Mobile
		3800-3900 Aero mobile Fixed Land mobile		
		3900-3950 Aero mobile		3900-3950 Aero mobile Broadcasting
		3950-4000 Broadcasting Fixed		3950-4000 Broadcasting Fixed
7000-7100 kHz	7000-7100 Amateur			
7100-7300 kHz		7100-7300 Broadcasting	7100-7300 Amateur	7100-7300 Broadcasting
14,000-14,350 kHz	Amateur			
21,000-21,450 kHz	Amateur			
28,000-29,700 kHz	Amateur			
50-54 MHz	—	Broadcasting	Amateur	Amateur
144-146 MHz	144-146 Amateur			
146-148 MHz		146-148 Fixed Mobile	146-148 Amateur	146-148 Amateur
220-225 MHz		Aero navigation	Amateur Radiolocation	Aero navigation Radiolocation
420-450 MHz	—	430-440 Amateur Radiolocation	420-450 Amateur Radiolocation	420-450 Amateur Radiolocation

*Austria, Denmark, Finland, Ireland, Netherlands, Federal Republic of Germany, Rhodesia and Nyasaland, United Kingdom, Switzerland, Czechoslovakia, and the Republic of South Africa and Territory of South West Africa may allocate up to 200 kHz to their amateur service within the band 1715-2000 kHz, taking steps to protect the fixed and mobile services of other countries from harmful interference. The mean power of these amateur stations shall not exceed 10 watts.

†The Loran system has priority. Other services to which the band is allocated may use any frequency in this band provided that they do not cause harmful interference to the Loran system.

Note — these allocations are subject to possible revision at the 1979 WARC in Geneva. Readers should obtain an up-to-date table after that date.

Boats of all sizes and types have carried Amateur Radio with them to all parts of the globe. Most of the boating enthusiasts who are radio amateurs value the service for the companionship it provides and for the ability to trade viewpoints with others of the same interest. It's a welcome passtime for the becalmed, the beached, or during the season when the craft is stored out of reach of winter's harsh treatment. It's a means of keeping in touch, as practiced by Thor Hyerdahl on several of his expeditions. Far beyond that, it has saved lives and property of countless victims of circumstance in our unpredictable oceans.

Amateur Radio is a great hobby, but far greater than that, it is a communications service, recognized as such by the United States and by many other governments around the world. What makes it so attractive to so many dedicated people? More than likely it is the infinite variety of things that can be done by amateurs, and the equally great variety of people who share their interests and provide comment and companionship wherever they may be. Aside from these attractions, the pride in what we have and what we have done makes amateurs eager to welcome a newcomer, yet ever watchful that our service maintains its position of high esteem. Amateurs will be happy to share their service with you in your quiet anchorage, or as your bow points to a distant horizon.

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